DOCUMENT RESUME

ED 256 950 CE 041 521

TITLE	Curriculum Development--Post-Secondary Electro-Mechanical Technology. Parts I-IV.
INSTITUTION	Texas State Technical Inst., Sweetwater.
SPONS AGENCY	Texas Education Agency, Austin. Dept. of Occupational Education and Technology.
PUB DATE	84
NOTE	1,015p.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF07 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; *Competency Based Education; Criterion Referenced Tests; Electric Motors; *Electromechanical Technology; Energy; Force; Guidelines; *Hydraulics; Job Skills; Learning Activities; *Mechanical Equipment; Mechanics (Physics); Motion; Physics; Postsecondary Education; *Power Technology; Pressure (Physics); State Curriculum Guides; Student Evaluation; *Technical Education
IDENTIFIERS	*Pneumatics; Texas

ABSTRACT

This curriculum guide consists of materials for use in teaching a four-part course in electromechanical technical technology. The first part contains nine units dealing with hydraulics and nine units on pneumatics. Addressed in the individual units are the following topics: an introduction to hydraulics; control of hydraulic energy; check valves and accumulators; flow control valves; directional control valves; pressure control valves; pilot-operated controls; hydraulic pumps and motors; fluids, reservoirs, coolers, and filters; force transmission; energy transmission and gas laws; control of pneumatic energy; compressors; compressed air and its conditioning and distribution; check valves, cylinders, and motors; directional control valves; flow control valves, exhaust, and silencers; and air preparation. The second part contains four units dealing with electric motors and controls and six units on digital electronics. Addressed in the individual units are the following topics: direct current (DC) motors, DC controls, alternating current (AC) motors, AC controls, digital fundamentals, digital circuits, Boolean algebra, flip-flops, sequential logic circuits, and combinational logic circuits. The third part contains five units dealing with power distribution and seven units on mechanical devices. Addressed in the individual units are the following topics: the basics of power distribution, raceways and conductors, feeders and branches, grounding devices, transformers, gears, mechanisms, drives, linkages, linking mechanisms, and cams. The fourth part contains five units dealing with microprocessors and interfacing and one unit on automation. Addressed in the individual units are the following topics: microprocessor architecture, input and output, standard interfaces, analog-to-digital interfaces and peripheral equipment, procedures for troubleshooting microprocessors, and automated systems. Each unit contains some or all of the following: objectives, suggested activities, notes to the instructor, student guidelines, information sheets, job sheets, assignment sheets, criterion-referenced tests, and test answers. (MN)

TX84:3111

ED256950

"CURRICULUM DEVELOPMENT - POST-SECONDARY ELECTRO-MECHANICAL TECHNOLOGY"

SWEETWATER

PART I

TEXAS STATE TECHNICAL INSTITUTE
SWEETWATER, TEXAS

1984

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ELECTRO-MECHANICAL TECHNOLOGY

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USE OF THIS PUBLICATION

This publication is designed to assist teachers in improving instruction. As this publication is used, it is hoped that student performance will improve.

Instructional material in this publication is written in terms of student performance using measureable objectives. This is an innovative approach to teaching that accents and augments the teaching-learning process. Criterion referenced evaluation instruments are provided for a uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from this publication: motivation, personalization, and localization. These areas are left to the individual instructors and the instructors should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

USE OF THIS PUBLICATION

Instructional Units

Careful study of each instructional unit by the teacher will help him determine:

- A. The amount of material that can be covered in each class period.
- B. The skills which must be demonstrated.
  - 1. Supplies needed.
  - 2. Equipment needed.
  - 3. Amount of practice needed.
  - 4. Amount of class time needed for demonstrations.
- C. Supplementary materials such as pamphlets and filmstrips that must be ordered.
- D. Resource people that must be contacted.

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of his students and community. When a teacher adds objectives, he should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. The activities are listed according to whether they are the responsibility of the instructor or the student.

USE OF THIS PUBLICATION

Instructor: Duties of the instructor will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Students: Student activities are listed which will help the student to achieve the objectives for the unit.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives of the unit. The teacher will find that information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skills specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for a student to follow if he has missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances he might reasonable expect from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

USE OF THIS PUBLICATION

Test and Evaluation

Paper pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the terminal objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

INTRODUCTION TO HYDRAULICS

UNIT I

INTRODUCTION TO HYDRAULICS

INTRODUCTION TO HYDRAULICS

UNIT I

OBJECTIVE

After completing this unit the student should be able to discuss how physical laws are applied to hydraulics, explain how forces and energy are transmitted in liquids and tell the relationship of atmospheric pressure to the suction side of a pump. This knowledge will be shown by completing end-of-chapter exercises, lab checkout activities, lab procedures, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Describe the relationship between force, friction, and inertia.
2. Relate different kinds of energy and work to the conservation of energy.
3. Give a relationship between pressure and the transmission of energy.
4. Express how force is transmitted through a liquid using the properties of liquids.
5. Describe how the bourdon and plunger gage work.
6. Tell how a cylinder converts pressure to force.
7. Describe how intensifiers aid in the performance of work.
8. Relate how an accumulator stores up energy.
9. Tell what part resistance and friction play in a positive displacement pump.
10. Relate three ways that heat is generated in hydraulics.
11. Describe what part pressure plays at the suction side of a pump.
12. Explain why cavitation is harmful to a pump.
13. Demonstrate the ability to
    - A. Set maximum pump pressure
    - B. Determine pump cavitation
    - C. Recognize psuedo-cavitation in pumps
    - D. Measure pump flow rate and check out a pump

INTRODUCTION TO HYDRAULICS

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with unit procedure sheets, text, and lab manual.

  C. Make transparencies.

  D. Discuss unit objectives, specific objectives, and procedure sheets.

  E. Discuss Chapter 1-3 and exercises.

  F. Discuss lab TCI - A, B, C, D, and checkout activities.

  G. Assist students with chapter exercises.

  H. Assist students with lab TCI - A, B, C, D, and checkout activities.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheet

  C. Take test.

Unit I

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Text.
- D. Videotape (optional).
- E. Lab Manual.
- F. Test.
- G. Answers to chapter exercises.
- H. Answers to test.

II. References

- A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.
- B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol, Inc., 1983.
- C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.
- D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.
- E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.
- F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

UNIT I

III. Additional Material

A. Introduction to Hydraulics, Austin, Texas Extension Instruction and Materials Center, UT, 1983.

INTRODUCTION TO HYDRAULICS

UNIT I

PROCEDURE SHEET

____1. Study Fluid power symbols in your text A-1 through A-17.

____2. Study Chapter 1, The Physical World of a Machine, in your text.

____3. Watch IHT Videotape Supplement for Chapter 1.

____4. Do Exercise for Chapter 1, pages 1-8.

____5. Stop Have the instructor evaluate Exercise 1 before your continue.

____6. Study Chapter 2, Hydraulic Transmission of Force and and Energy, in your text.

____7. Watch IHT Videotape Supplement for Chapter 2.

____8. Do Exercises for Chapter 2, pages 2-12 through 2-13.

____9. Stop Have the instructor evaluate Exercise 2 before you continue.

____10. Study Chapter 3, Operation at the Suction Side of a Pump, in your text.

____11. Watch IHT Videotape Supplement for Chapter 3.

____12. Do Exercise for Chapter 3, pages 3-9 through 3-10.

____13. Stop Have the instructor evaluate Exercise 3 before you continue.

____14. Study Lab TC 1-A Set Maximum Pump Pressure.

____15. Do Lab TC 1-A as described in your lab manual.

____16. Complete Checkout activities for Lab TC 1-A in your lab manual.

____17. Stop Have the instructor rate your performance for Lab TC 1-A and evaluate your Checkout Activities for Lab TC 1-A before you continue.

____18. Study Lab TC 1-B Pump-Cavitation

____19. Do Lab TC 1-B as described in your lab manual.

____20. Complete Checkout Activities for Lab TC 1-B in your lab manual.

PROCEDURE SHEET

____21.	Stop	Have the instructor rate your performance for Lab TC 1-B and evaluate your Checkout Activities, Lab TC 1-B, before you continue.
____22.	Study	Lab TC 1-C-Pump Pseudo-Cavitation.
____23.	Do	Lab TC 1-C as described in your lab manual.
____24.	Complete	Checkout Activities for Lab TC 1-C in your lab manual.
____25.	Stop	Have the instructor rate your performance for Lab TC 1-C and evaluate your Checkout Activities for TC 1-C before you continue.
____26.	Study	Lab TC 1-D, Determining the Flow Rate Developed by a Pump.
____27.	Do	Lab TC 1-D as described in your lab manual.
____28.	Complete	Checkout Activities for Lab TC 1-D in your lab manual.
____29.	Stop	Have the instructor rate your performance on page TC 1-D and evaluate your Checkout Activities on page TC 1-D before you continue.
____30.	Review	Chapter 1, 2, and 3 in your text and Lab TC 1-A, B, C & D in your lab manual.
____31.	Take	Hydraulic Test #1.
____32.	Stop	Have your instructor evaluate Hydraulic Test #1. If your instructor is satisfied with your performance, continue on to Unit II. Otherwise review the areas suggested by your instructor and repeat Steps 31 and 32.

INTRODUCTION TO HYDRAULICS

UNIT I

TEST

1. Describe how force, friction, and inertia are involved in the kicking of a ball.

2. Relate different kinds of energy and work to the conservation of energy.

3. Give a relationship between pressure and the transmission of energy.

4. Explain how force is transmitted through a liquid using the properties of liquids.

TEST

5. Describe how the bourdon and plunger gage work.

6. Tell how a cylinder converts pressure to force.

7. Describe how intensifiers aid in the performance of work.

8. Relate how an accumulator stores up energy.

9. Tell what part resistance and friction play in a positive displacement pump.

TEST

10. Relate three ways that heat is generated in hydraulics.

11. Describe what part pressure plays at the suction side of a pump.

12. Explain why cavitation is harmful to a pump.

13. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

INTRODUCTION TO HYDRAULICS

UNIT I

TEST ANSWERS

1. One applies a force to a ball (the kicking) and the ball resists (inertia) the resulting motion because of friction.

2. The sum of the potential and kinetic energy of a system before work is done on the system is equal to the sum of the final potential and final kinetic energies plus the work that was done on the system.

3. Since a pressure exerts a force over an area of a medium and this medium is moving then energy is transmitted through this medium.

4. Since liquids are relatively incompressible because the molecules are not attracted to each other, any force applied to one molecule will be transmitted to the next molecule because of this repelling attraction.

5. The needle on the bourdon gage tends to straighten out as the pressure increases while in a plunger gage the needle moves through a linkage because of the change of pressure in a cylinder.

6. Since a force applied to a liquid in a cylinder is transmitted throughout the liquid in the cylinder, the force will be transmitted in a straight line manner to the piston in the cylinder.

7. An intensifier multiplier pressure through using Pascal law and having large piston areas connected through cylinders to small piston areas.

8. An accumulator stores hydraulic pressure in some sort of tank and when the pressure is released, the stored pressure releases working energy through flow and pressure.

9. When liquid moves it develops a friction, and therefore a resistance along the walls through which it flows and the object being moved by the liquid develops a resistance to the movement and hence a friction.

10. Heat is generated by a moving liquid by its viscosity, friction, and changing direction.

11. When the pump is not operating both sides of the pump are in pressure equilibrium, but when the pump is operating the suction side has a pressure lower than atmosphere, therefore causing the liquid to try to reach equilibrium.

TEST ANSWERS

12. Cavitation causes cavities in a liquid which in turn interferes with lubrication and also causes extreme high pressures at metal surfaces which destroy metal surfaces.

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INTRODUCTION TO HYDRAULICS

UNIT II

CONTROL OF HYDRAULIC ENERGY

CONTROL OF HYDRAULIC ENERGY

UNIT II

OBJECTIVE

After completing this unit, the student should be able to analyze how a hydraulic actuator works and calculate the horsepower it generates and describe how different valves control pressure or flow rate. This knowledge will be shown by completing end-of-chapter exercises, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit the student should be able to

1. List the components of a cylinder.
2. Relate cylinder force to cylinder volume.
3. Describe how a hydraulic motor works.
4. Define the parts of the system and cylinder horsepower equation.
5. Give a sample of using the motor horsepower equation.
6. Explain how valves can control pressure.
7. Describe how a pressure control valve works.
8. Tell how a double acting cylinder operates.
9. Describe how a directional control valve works.
10. Explain how a flow control valve works.
11. Demonstrate the ability to
    - A. Use valve spool variations to control double-acting cylinder reciprocation.
    - B. Determine cylinder entering and discharge flow rates.
    - C. Measure effects of cylinder cushions.

CONTROL OF HYDRAULIC ENERGY

Unit II

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with unit procedure sheets, text and lab manual.

   C. Make transparencies.

   D. Discuss unit objective, specific objectives, and procedure sheets.

   E. Discuss chapter 4 and exercises.

   F. Discuss labs TC2 - A, B, C, and checkout activities.

   G. Assist students with chapter exercise.

   H. Assist students with labs TC2 - A, B, C.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

UNIT II

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheets.

   C. Text.

   D. Videotape (optional).

   E. Lab Manual.

   F. Test.

   G. Answers to chapter exercises.

   H. Answers to test.

II. References

   A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.

   B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.

   C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.

   D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.

   E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

   F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

CONTROL OF HYDRAULIC ENERGY

UNIT II

PROCEDURE SHEET

_____1.	Study	Chapter 4, Hydraulic Actuators, in you text.
_____2.	Watch	IHT Videotape Supplement for Chapter 4.
_____3.	Do	Exercise for Chapter 4 in your text.
_____4.	Stop	Have the instructor evaluate Exercise 4 before you continue.
_____5.	Study	Chapter 5 Control of Hydraulic Energy, in your text.
_____6.	Watch	IHT Videotape Supplement for Chapter 5.
_____7.	Do	Exercise for Chapter 5 in your text.
_____8.	Stop	Have your instructor evaluate Exercise 5 before you continue.
_____9.	Study	Lab TC 2-A Cylinder Reciprocation in your lab manual.
_____10.	Do	Lab TC 2-A as described in your lab manual.
_____11.	Stop	Have your instructor evaluate Lab TC-A before you continue.
_____12.	Complete	Checkout Activities for Lab TC 2-A in your lab manual.
_____13.	Stop	Have the instructor evaluate your Checkout Activities for Lab TC 2-A before you continue.
_____14.	Study	Lab TC 2-B Cylinder Entering and Discharge Flow Rates in your lab manual.
_____15.	Do	Lab TC 2-B as described in your lab manual.
_____16.	Stop	Have the instructor rate your performance for Lab TC 2-B in your lab manual before you continue.
_____17.	Complete	Checkout Activities for lab TC 2-B in your lab manual.
_____18.	Stop	Have the instructor evaluate your Checkout Activities before you continue.

PROCEDURE SHEET

____19. Study Lab TC 2-C, Effect of Cylinder Cushion, in your lab manual.

____20. Do Lab TC 2-C as described in your lab manual.

____21. Stop Have the instructor rate your performance for Lab TC 2-C.

____22. Complete Checkout Activities for Lab TC 2-C in your lab manual.

____23. Stop Have the instructor evaluate your Checkout Activities for Lab TC-2 before you continue.

____24. Review Chapters 4 and 5 in your text and Lab TC 2-A, B and C in your lab manual.

____25. Take Hydraulic Test #2.

____26. Stop Have your instructor evaluate Hydraulic Test #2. If your instructor is satisfied with your performance, continue on to Unit III. Otherwise review the areas suggested by your instructor and repeat Steps 25 and 26.

CONTROL OF HYDRAULIC ENERGY

UNIT II

TEST

1. List the components of a cylinder.

2. Relate cylinder force to cylinder volume.

3. Describe how a hydraulic motor works.

4. Define the parts of the system and cylinder horsepower equation.

5. Give an example of the motor horsepower equation.

TEST

6. Explain how valves can control pressure.

7. Describe how a pressure control valve operates.

8. Tell how a double-acting cylinder operates.

9. Describe how a directional control valve operates.

10. Explain how a flow control valve works.

TEST

11. STOP. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

CONTROL OF HYDRAULIC ENERGY

UNIT II

TEST ANSWERS

1. A cylinder consists of a cylinder body with an inlet at one end and an outlet at the other end, a closure at each end, and a movable piston attached to a piston rod.

2. A force pushes/pulls the piston up/down the cylinder moving through the cylinder volume.

3. The shaft in a hydraulic motor, located off center and connected to a shaft which resists motion, rotates when fluid enters the inlet due to the off balance of pressure between the inlet and outlet. As the inlet liquid reaches the outlet past the liquid exits and starts the process over again.

4. The total hydraulic system horsepower is equal to the gallon per minute flowing times the pressure times a constant--0.000583.

5. A hydraulic motion develops 200 in-lb of torque at 500 revs per minute and develops 1.6 horsepower.

$$\frac{(200)500}{63025}$$

6. Through a pressure control over/under pressure signals a valve to open or close. Levels can open or close a valve.

7. A pressure control valve consists of a valve body with a primary and secondary passage and an internal moving part. The internal part is activated by pressure which connects or disconnects passage in a valve body allowing liquid to follow another path.

8. The double-acting has a part at either end of the cylinder body by which fluid can enter or leave which in turn controls the bi-direction of the piston.

9. The ~~typed~~ directional control valve consists of a valve body with four internal passages and a sliding spool which connects and disconnects passages.

10. A flow control valve consists of a valve body and adjustable part. By moving the adjustable part the flow rate is changed.

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INTRODUCTION TO HYDRAULICS

UNIT III

CHECK VALVES AND ACCUMULATORS

CHECK VALVES AND ACCUMULATORS

UNIT III

OBJECTIVE

After completing this unit the student should be able to explain how check valves work and for what they are used. The student should also be able to name the types of accumulators and how they function and describe the parts of cylinders and how they work. This knowledge will be shown by completing the end of chapter exercise, lab checkout activities, lab procedures, and unit test with a miniaum score of 80 percent.

SPECFIC OBJECTIVES

After completing this unit, the student should be able to:

1. Explain how a check valve works in a circuit.
2. Explain how a pilot operated check valve works in a circuit.
3. Name six types of accumulators and how they function.
4. Describe how an accumulator is used in a circuit.
5. Discuss hydraulic cylinders using hydraulic cylinder terminology.
6. Explain how a double-rod cylinder is used in a circuit.
7. Explain how a 2:1 cylinder is used in a regenerative circuit.
8. Demonstrate the ability to
    - A. Teardown and reassemble an air cylinder.
    - B. Understand pressure and application limits of an air cylinder.
    - C. Troubleshoot hydraulic check valves.
    - D. Inspect pilot operated check valves.
    - E. Troubleshoot failed cylinders.
    - F. Disassemble and reassemble accumulators.

CHECK VALVES AND ACCUMULATORS

UNIT III

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with unit procedure sheets, text, and lab manual.

   C. Make transparencies.

   D. Discuss unit objective, specific objectives, and procedure sheets.

   E. Discuss Chapter 6.

   F. Discuss labs HML1 - A, B, C, D, E, F.

   G. Assist students with chapter exercises.

   H. Assist students with labs HML1 - A, B, C, D, E, F.

   I. Give test.

II. Students

   A. Read objective sheet

   B. Complete procedure sheet.

   C. Take test.

UNIT III

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Text.

  D. Videotape (optional).

  E. Lab Manual.

  F. Test.

  G. Answers to chapter exercises.

  H. Answers to test.

II. References

  A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.

  B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.

  C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.

  D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.

  E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

  F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

CHECK VALVES AND ACCUMULATORS

UNIT III

PROCEDURE SHEET

_____1. Study — Chapter 6, Check Valves, Accumulator, and Cylinder in your text.

_____2. Watch — IHT Videotape Supplement for Chapter 6.

_____3. Do — Exercise at the end of Chapter 6 in your text.

_____4. Stop — Have the instructor evaluate the exercise before you continue.

_____5. Study — Lab HML 1-A Air Cylinder Construction and Sealing in your lab manual.

_____6. Do — Lab HML 1-A Air Cylinder Construction and Sealing in your lab manual.

_____7. Stop — Have your instructor evaluate your performance for Lab HML 1-A before you continue.

_____8. Complete — Checkout Activities at the end of Lab HML 1-A.

_____9. Stop — Have the instructor evaluate checkout activities for Lab HML 1-A before you continue.

_____10. Study — Lab HML 1-B, Hydraulic Cylinder Construction and Sealing, in your lab manual.

_____11. Do — Lab HML 1-B, Hydraulic Cylinder Construction and Sealing in your lab manual.

_____12. Stop — Have your instructor evaluate your performance for Lab HML 1-B.

_____13. Complete — Checkout Activities for Lab HML 1-B.

_____14. Stop — Have the instructor evaluate the Checkout Activities for Lab HML 1-B.

_____15. Study — Lab HML 1-C, Hydraulic Check Valve, in your manual.

_____16. Do — Lab HML 1-C, Hydraulic Check Valve, in your lab manual.

_____17. Stop — Have the instructor evaluate your performance of Lab HML 1-C.

PROCEDURE SHEET

____18.	Complete	Checkout Activities for Lab HML 1-C.
____19.	Stop	Have the instructor evaluate your Checkout Activities.
____20.	Study	Lab HML 1-D, Pilot Operated Check Valve, in your lab manual.
____21.	Do	Lab HML 1-D, Pilot Operated Check Valve, in your lab manual.
____22.	Stop	Have the instructor evaluate your performance of Lab HML 1-D before you continue.
____23.	Complete	Checkout Activities for Lab HML 1-D.
____24.	Stop	Have the instructor evaluate the Checkout Activities for Lab HML 1-D.
____25.	Study	Lab HML 1-E, Failed Cylinder Inspection, in your lab manual.
____26.	Do	Lab HML 1-E, Failed Cylinder Inspection, in your lab manual.
____27.	Stop	Have the instructor rate your performance of Lab HML 1-E before you continue.
____28.	Complete	Checkout Activities for Lab HML 1-E.
____29.	Stop	Have the instructor evaluate the Checkout Activities for Lab HML 1-E before you continue.
____30.	Study	Lab HML 1-F, Accumulators, in your lab manual.
____31.	Do	Lab HML 1-F, Accumulators, in your lab manual.
____32.	Stop	Have the instructor rate your performance of Lab HML 1-F before you continue.
____33.	Complete	Checkout Activities for Lab HML 1-F.
____34.	Stop	Have the instructor evaluate the Checkout Activities for Lab HML 1-F before you continue.
____35.	Review	Chapter 6 in your text and Labs HML 1-A, B, C, D, E, F, in your lab manual.
____36.	Take	Hydraulics Test #3.
____37.	Stop	Have your instructor evaluate Hydraulics Test #3. If your instructor is satisfied with your performance, continue on to Unit IV. Otherwise review the areas suggested by your instructor and repeat Steps 36 and 37.

CHECK VALVES AND ACCUMULATORS

UNIT III

TEST

NAME______________________________ SCORE______________

1. Explain how a check valve works in a circuit.

2. Explain how a pilot operated check valve works in a circuit.

3. Name six types of accumulators and how they function.

    a.

    b.

    c.

    d.

    e.

    f.

TEST

4. Describe how an accumulator is used in a circuit.

5. Discuss hydraulic cylinders using hydraulic cylinder terminology.

6. Explain how a double-rod cylinder is used in a circuit.

7. Explain how a 2:1 cylinder is used in a regenerative circuit.

8. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

CHECK VALVES AND ACCUMULATORS

UNIT III

TEST ANSWERS

1. Fluid flow passes through a check valve in one controllable direction therefore the check valve performs the function of being a directional and a pressure valve.

2. One directional fluid flow is controlled by pilot pressure on a piston which in turn opens a check valve. The pilot operated valve can be placed in a line to a cylinder's piston to lock the load in place or until the pilot pressure is changed.

3. a. The weight-loaded accumulators are used to maintain constant pressure in mill and central hydraulic line circuits.

   b. The spring-loaded accumulator use an adjustable spring to maintain a pressure in a line and can be mounted in any position.

   c. The hydro-pneumatic accumulator uses compressed nitrogen gas to maintain a pressure in a line circuit.

   d. The piston type accumulator uses nitrogen gas on the other side of a piston to maintain a constant pressure in a line circuit.

   e. The diaphragm type accumulator uses nitrogen gas on one side of a flexible synthetic rubber membrane to maintain pressure in a line circuit.

   f. The bladder type accumulator has a bladder of nitrogen gas inside a metal shell which will maintain a constant pressure in a circuit.

4. Accumulators maintain pressure in circuit lines by compensating for pressure losses due to leakage or pressure increase caused by thermal expansion. They can also be a source of energy when the pressure in a line drops by supplying the missing pressure.

5. Hydraulic cylinder rods need positive sealing which is accomplished through a gland seal which wipes the rod dry and drains the accumulated fluid off in a gland drain. Hydraulic shock can occur when a cylinder's piston runs into the end of the cylinder. This shock is absorbed by cushions. The cushion can consist of a needle valve through which the accumulating fluid can pass to prevent the fluid pressure from building up in the cylinder. Adjustment of the piston travel can be accomplished through threaded stroke adjustor. Cylinders can be mounted in several

TEST ANSWERS

ways, among them are flange, trunnion side lug and side topped, clevis, tie rod and bolt mounting. If a cylinder pushes a load it is called a thrust load and if the cylinder pulls a load, the load is called a tension load.

6. Double-rod cylinders are required when a need for a cylinder to extend and retract at the same speed.

7. Since the rod on a 2:1 cylinder allows for a differential force on the piston when both sides of the piston are at the same pressure the rod will move in the direction of the enlarged rod. To refill the emptied rod side, a check valve is closed which refills the rod side and consequently running the piston in the opposite direction.

INTRODUCTION TO HYDRAULICS

UNIT IV

FLOW CONTROL VALVES

FLOW CONTROL VALVES

UNIT IV

OBJECTIVE

After completing the unit, the student should be able to distinguish between the different types of flow control valves and their uses. This knowledge will be shown by completing the exercise at the end of the chapter, lab procedures, lab checkout activities, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. List the three factors that affect flow through an orifice.
2. Describe how fluid flows through a gate valve.
3. Describe how fluid flows through a globe valve.
4. Describe why fluid flows through a needle valve in a circuit affected by pressure differential.
5. Describe when a restrictor type pressure compensated flow control valve is used in a circuit.
6. Describe how a bypass type pressure compensated flow control valve works.
7. Explain why a temperature-pressure compensated flow control valve is difficult to design.
8. Describe when a flow control valve is used as a meter-in circuit and when a meter-out circuit.
9. Demonstrate the ability to
    - A. Construct a needle valve.
    - B. Disassemble a flow control valve.
    - C. Troubleshoot a pressure compensated flow control valve.
    - D. Construct a pressure and temperature compensated flow control valve.
    - E. Replace parts on a deceleration valve.

SPECIFIC OBJECTIVES

F. Troubleshoot 2-way valves.

G. Use two-to-one cylinder regeneration to increase speed of pump flow.

D. Apply meter-in speed control valves to the hydraulic circuit.

E. Determine how flow varies with pressure change.

F. Maintain a constant flow rate with a control valve.

G. Determine pressure flow control with meter-out valve.

H. Apply a bleed-off flow control valve.

I. Install a bypass flow control valve.

J. Determine application of accumulators for hold and flow.

K. Apply the pilot operated check valve in a cylinder line.

L. Prevent cylinder pressure drop.

M. Apply flow divider valves.

FLOW CONTROL VALVES

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with unit procedure sheets, text, and lab manual.

   C. Make transparencies.

   D. Discuss unit objective, specific objectives, and procedure sheets.

   E. Discuss chapter 7 and exercise.

   F. Discuss labs HML2 - A, B, C, D, E, F, and labs TC3 - A, B, C, D, E, F, G, H, I, J, K, and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist student with labs HML2 - A, B, C, D, E, F, and lab TC3 - A, B, C, D, E, F, G, H, J, K , and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

UNIT IV

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Text.
- D. Videotape (optional).
- E. Lab Manual.
- F. Test.
- G. Answers to chapter exercises.
- H. Answers to test.

II. References

- A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.
- B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.
- C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.
- D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.
- E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.
- F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

FLOW CONTROL VALVES

UNIT IV

PROCEDURE SHEET

_____1. Study Chapter 7, Flow Control Valves, in your text.

_____2. Watch IHT Videotape Supplement for Chapter 7.

_____3. Do Exercise for Chapter 7 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab HML 2-A Needle Valve in your lab manual.

_____6. Do Lab HML 2-A

_____7. Stop Have the instructor rate your performance for Lab HML 2-A before you continue.

_____8. Complete Checkout Activities for Lab HML 2-A.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab HML 2-A.

_____10. Study Lab HML 2-B, Flow Control Valve, in your lab manual.

_____11. Do Lab HML 2-B

_____12. Stop Have the instructor rate your performance for Lab HML 2-B.

_____13. Complete Checkout Activities for Lab HML 2-B.

_____14. Stop Have your instructor evaluate the Checkout Activities for Lab HML 2-B.

_____15. Study Lab HML 2-C, Pressure Compensated Flow Control, in your lab manual.

_____16. Do Lab HML 2-C

_____17. Stop Have the instructor rate your performance for Lab HML 2-C.

_____18. Complete Checkout Activities for Lab HML 2-C.

_____19. Stop Have your instructor evaluate the Checkout Activities for Lab HML 2-C.

PROCEDURE SHEET

____20. Study Lab HML 2-D, Pressure and Temperature Compensated Flow Control, in your lab manual.

____21. Do Lab HML 2-D

____22. Stop Have the instructor rate your performance for Lab HML 2-D.

____23. Complete Checkout Activities for Lab HML 2-D.

____24. Stop Have the instructor evaluate Checkout Activities for HML 2-D.

____25. Study Lab HML 2-E, Deceleration Valve, in your lab manual.

____26. Do Lab HML 2-E

____27. Stop Have your instructor rate your performance for Lab HML 2-E.

____28. Complete Checkout Activities for Lab HML 2-E.

____29. Stop Have the instructor evaluate the Checkout Activities for Lab HML 2-E.

____30. Study Lab HML 2-F, Failed Valve Inspection, in your lab manual.

____31. Do Lab HML 2-F

____32. Stop Have the instructor rate your performance for Lab HML 2-F before you continue.

____33. Complete Checkout Activities for Lab HML 2-F.

____34. Stop Have the instructor evaluate Checkout Activities for Lab HML 2-F.

____35. Study Lab TC 3-A, Two-to-One Cylinder Regeneration, in your lab manual.

____36. Do Lab TC 3-A

____37. Stop Have the instructor rate your performance for Lab TC 3-A.

____38. Complete Checkout Activities for Lab TC 3-A.

____39. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-A.

PROCEDURE SHEET

____40.	Study	Lab TC 3-B, Meter-In Needle Valve, in your lab manual.
____41.	Do	Lab TC 3-B.
____42.	Stop	Have the instructor rate your performance for Lab TC 3-B.
____43.	Complete	Checkout Activities for Lab TC 3-B.
____44.	Stop	Have the instructor evaluate Checkout Activities for Lab TC 3-B.
____45.	Study	Lab TC 3-C, Flow Metering with Varying Pressure (Non-Compensated), in your lab manual.
____46.	Do	Lab TC 3-C.
____47.	Stop	Have the instructor rate your performance for Lab TC 3-C.
____48.	Complete	Checkout Activities for Lab TC 3-C.
____49.	Stop	Have the instructor evaluate Checkout Activities for Lab TC 3-C.
____50.	Study	Lab TC 3-D, Pressure Compensated Flow Control with Varying Pressure, in your lab manual.
____51.	Do	Lab TC 3-D.
____52.	Stop	Have the instructor rate your performance for Lab TC 3-D.
____53.	Complete	Checkout Activities for Lab TC 3-D.
____54.	Stop	Have the instructor evaluate Checkout Activities for Lab TC 3-D.
____55.	Study	Lab TC 3-E, Pressure Compensated Meter-Out Flow Control, in your lab manual.
____56.	Do	Lab TC 3-E.
____57.	Stop	Have the instructor rate your performance for Lab TC 3-E.
____58.	Complete	Checkout Activities for Lab TC 3-E.
____59.	Stop	Have the instructor evaluate Checkout Activities for Lab TC 3-E.

PROCEDURE SHEET

____60. Study Lab TC 3-F, Pressure Compensated Bleed Off Flow Control, in your lab manual.

____61. Do Lab TC 3-F

____62. Stop Have the instructor rate your performance for Lab TC 3-F.

____63. Complete Checkout Activities for Lab TC 3-F.

____64. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-F.

____65. Study Lab TC 3-G, Bypass Flow Control, in your lab manual.

____66. Do Lab TC 3-G

____67. Stop Have the instructor rate your performance for Lab TC 3-G.

____68. Complete Checkout Activities for Lab TC 3-G.

____69. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-G.

____70. Study Lab TC 3-H, Applying Accumulators for Hold and Flow, in your lab manual.

____71. Do Lab TC 3-H.

____72. Stop Have the instructor rate your performance for Lab TC 3-H.

____73. Complete Checkout Activities for Lab TC 3-H.

____74. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-H.

____75. Study Lab TC 3-I, Pilot Operated Check Valve, in your lab manual.

____76. Do Lab TC 3-I.

____77. Stop Have the instructor rate your performance for Lab TC 3-I.

____78. Complete Checkout Activities for Lab TC 3-I.

____79. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-I.

PROCEDURE SHEET

____80. Study Lab TC 3-J, Pressure Port Check, in your lab manual.

____81. Do Lab TC 3-J.

____82. Stop Have the instructor rate your performance for Lab TC 3-J.

____83. Complete Checkout Activities for Lab TC 3-J.

____84. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-J.

____85. Study Lab TC 3-K, Flow Divider and Combiner Valves, in your lab manual.

____86. Do Lab TC 3-K.

____87. Stop Have the instructor rate your performance for Lab TC 3-K.

____88. Complete Checkout Activities for Lab TC 3-K.

____89. Stop Have the instructor evaluate Checkout Activities for Lab TC 3-K.

____90. Review Chapter 7 in your text and Labs HML 2-A, B, C, D, E, F; TC3-A, B, C, D, E, F, G, H, I, J, K in your lab manual.

____91. Take Hydraulics Test #4.

____92. Stop Have your instructor evaluate Hydraulics Test #4. If your instructor is satisfied with your performance, continue on to Unit V. Otherwise review the areas suggested by your instructor and repeat Steps 91 and 92.

FLOW CONTROL VALVES

UNIT IV

TEST

NAME____SCORE___________

1. List the three factors that affect flow through an orifice.

   a.

   b.

   c.

2. Describe how fluid flows through a gate valve.

3. Describe how fluid flows through a globe valve.

4. Describe why fluid flows through a needle valve in a circuit affected by pressure differential.

TEST

5. Describe when a restrictor type pressure compensated flow control valve is used in a circuit.

6. Describe how a bypass type pressure compensated flow control works.

7. Explain why a temperature-pressure compensated flow control valve is difficult to design.

8. Describe when a flow control valve is used as a meter-in circuit and when it's used as a meter-out circuit.

9. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

FLOW CONTROL VALVES

UNIT IV

TEST ANSWERS

1. Three factors that affect flow through an orifice are: (a) size of the orifice (b) pressure differential across the orifice, and (c) temperature of the fluid.

2. A gate valve has a flow path straight through its center. The size of the path is changed by turning a handle which positions a gate across the flow path.

3. A globe has a flow path that has a 90° bend in it and then passes through an opening which is the seat of a plug which controls the size of the opening.

4. In this type of circuit, the relief valve is set at, say, 600 PSI and the pressure needed to overcome the resistance of the load is 300 PSI. The resulting 300 PSI pressure differential develops the fluid flow.

5. Since the restrictor type valve has a movable spool which is controlled by an internal pilot passage, the spool will move to restrict the flow when the pressure attempts to rise above the valve of the compensator spring.

6. The spool spring has a valve of, say, 100 PSI, which limits the pressure ahead of a needle valve to 100 PSI. When the pressure ahead of the needle valve attempts to exceed the 100 PSI, the spring loaded spool uncovers the tank and flow is directed to the tank until the pressure return to 100 PSI.

7. Fluid flow through a sharp edged orifice is not affected by temperature but the orifice must be machined exactly and held to very close tolerances.

8. Normally flow control valves are placed in the circuit directly before the actuator whose speed it was controlling. The workload pressure was continously a positive valve. But in a case where the workload changes direction, the workload pressure can go to zero and no control. By placing the valve at the outlet of the actuator this again gives positive speed control.

INTRODUCTION TO HYDRAULICS

UNIT V

DIRECTIONAL CONTROL VALVES

DIRECTIONAL CONTROL VALVES

UNIT V

OBJECTIVE

After completing this unit, the student should be able to identify the different directional control valves and how they operate. The knowledge will be shown by completing the end-of-chapter exercise, lab procedures, lab checkout activities, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit the student should be able to

1. Explain the function of the four-way directional control valve in a circuit.
2. Explain the function of the three-way directional control valve in a circuit.
3. Explain the function of the two-way directional control valve in a circuit.
4. Describe directional valve spools.
5. List five ways a valve spool is actuated.
6. Describe how a solenoid operates a directional valve.
7. Tell in what two positions spring offset two-way and three-way valves can be when not energized.
8. List four center conditions for four-way directional valves.
9. Tell how the P, T, B and A passages are oriented in an open center condition and a closed center condition.
10. Give an advantage of a directional valve with a tandem center spool.
11. Give an advantage of a directional valve with a float center spool.
12. Explain how springs and hydraulic pressure hold a three-position directional valve in its center position.
13. Describe how the choke control operates in a directional control valve.

SPECIFIC OBJECTIVES

14. Demonstrate the ability to

    A. Troubleshoot the piloted slave or piggyback directional control valve.

    B. Determine operation of sandwich flow control valves.

    C. Tear down a failed valve.

    D. Troubleshoot flow divider and combiner valves.

    E. Troubleshoot multiple-spool directional control valves.

    F. Recognize multiple spool directional control valves.

    G. Apply air bleed valves, hose burst and shuttle valves to a hydraulic circuit.

DIRECTIONAL CONTROL VALVES

UNIT V

SUGGESTED ACTIVITIES

I. Instructor

A. Provide students with objective sheet.

B. Provide students with unit procedure sheets, text, and lab manual.

C. Make transparencies.

D. Discuss unit objective, specific objectives, and procedure sheets.

E. Discuss chapter 8 and exercise.

F. Discuss labs HML3 - A, B, C, D, E, and labs TC3 - L, M and checkout activities.

G. Assist students with chapter exercises.

H. Assist students with labs HML3 - A, B, C, D, E, and labs TC3 - L, M, and checkout activities.

II. Student

A. Read objective sheet.

B. Complete procedure sheet.

C. Take test.

UNIT V

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Text.
- D. Videotape (optional).
- E. Lab Manual.
- F. Test.
- G. Answers to chapter exercises.
- H. Answers to test.

II. References

A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.

B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.

C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.

D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.

E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

DIRECTIONAL CONTROL VALVES

UNIT V

PROCEDURE SHEET

_____1. Study Chapter 8, *Directional Control Valves*, in your text.

_____2. Watch IHT Videotape Supplement for Chapter 8.

_____3. Do Exercise for Chapter 8 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab HML 3-A, *Directional Control Valves*, in your lab manual.

_____6. Do Lab HML 3-A

_____7. Stop Have the instructor rate your performance for Lab HML 3-A before you continue.

_____8. Complete Checkout Activities for Lab HML 3-A.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab HML 3-A.

____10. Study Lab HML 3-B, *Sandwich Flow Control*, in your lab manual.

____11. Do Lab HML 3-B

____12. Stop Have the instructor rate your performance for Lab HML 3-B before you continue.

____13. Complete Checkout Activities for Lab HML 3-B.

____14. Stop Have the instructor evaluate the Checkout Activities for Lab HML 3-B.

____15. Study Lab HML 3-C, *Failed Valve Inspection*, in your lab manual.

____16. Do Lab HML 3-C

____17. Stop Have the instructor rate your performance for Lab HML 3-C before you continue.

____18. Complete Checkout Activities for Lab HML 3-C.

____19. Stop Have the instructor evaluate the Checkout Activities for Lab HML 3-C.

PROCEDURE SHEET

____20.	Study	Lab HML 3-D, Flow Divider and Combiner Valves, in your lab manual.
____21.	Do	Lab HML 3-D.
____22.	Stop	Have the instructor rate your performance for Lab HML 3-D before you continue.
____23.	Complete	Checkout Activities for Lab HML 3-D.
____24.	Stop	Have the instructor evaluate the Checkout Activities for Lab HML 3-D.
____25.	Study	Lab HML 3-E, Multiple Spool Directional Control Valves, in your lab manual.
____26.	Do	Lab HML 3-E.
____27.	Stop	Have the instructor rate your performance for Lab HML 3-E before you continue.
____28.	Complete	Checkout Activities for Lab HML 3-E.
____29.	Stop	Have the instructor evaluate the Checkout Activities for Lab HML 3-E.
____30.	Study	Lab TC 3-L, Multiple Spool Directional Control Valves, in your lab manual.
____31.	Do	Lab TC 3-L.
____32.	Stop	Have the instructor rate your performance for Lab TC 3-L.
____33.	Complete	Checkout Activities for Lab TC 3-L.
____34.	Stop	Have the instructor evaluate Checkout Activities for Lab TC 3-L.
____35.	Study	Lab TC 3-M, Air Bleed, Hose Burst and Shuttle, in lab manual.
____36.	Do	Lab TC 3-M.
____37.	Stop	Have the instructor rate your performance for Lab TC 3-M.
____38.	Complete	Checkout Activities for Lab TC 3-M.
____39.	Stop	Have the instructor evaluate Checkout Activities for Lab TC 3-M.

PROCEDURE SHEET

____40. Review Chapter 8, Directional Control Valves and Labs HM 3A-3E and TC 3L, 3M.

____41. Take Hydraulics Test #5.

____42. Stop Have your instructor evaluate Hydraulics Test #5. If your instructor is satisfied with your performance, continue on to Unit VI. Otherwise review the areas suggested by your instructor and repeat Steps 41 and 42.

DIRECTIONAL CONTROL VALVES

UNIT V

TEST

NAME______________________________ SCORE__________

1. Explain the function of the four-way directional control valve in a circuit.

2. Explain the function of the three-way directional control valve in a circuit.

3. Explain the function of the two-way directional control valve in a circuit.

4. Describe directional valve spools.

TEST

5. List five ways a valve spool is actuated

   a.

   b.

   c.

   d.

   e.

6. Describe how a solenoid operates a directional valve.

7. Tell in what two positions spring offset two-way and three-way valves can be when not energized.

8. List four center conditions for four-way directional valves.

   a.

   b.

   c.

   d.

TEST

9. Explain how the P, T, B, and A passages are oriented in an open center condition and a closed center condition.

10. Give an advantage of a directional valve with a tandem center spool.

11. Give an advantage of a directional valve with a float center spool.

12. Explain how springs and hydraulic pressure hold a three-position directional valve in its center position.

13. Describe how the choke control operates in a directional control valve.

14. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

DIRECTIONAL CONTROL VALVES

UNIT V

TEST ANSWERS

1. The function is to cause the reverse motion of a cylinder or hydraulic motor.

2. The function is to pressurize one part when the spool is in one extreme position and pressurize the other part when the spool is in the other extreme position.

3. The function is to connect two passages when the spool is in one position and close the passage when the spool is in the other position.

4. The spool consists of a shaft to which skirts are equally spaced apart. The skirts are known as lands.

5. The spool is actuated by mechanical, electrical, hydraulic, pneumatic or human means.

6. The plunger is surrounded by a coil of wire which when magnitized will move one direction or another depending on the direction of the current in the wire.

7. Two-way and three-way spring offset valves can either be in a normally open or a normally closed position.

8. Four outer conditions are:

    a. Open, allows between all passages.

    b. Closed, all passages are closed.

    c. Tanden, P and T passages are connected and A and B passages are connected.

    d. Float outer, A, B, and T passages are open while P is blocked.

9. In the open center conditon, all passages are connected and in the closed outer condition, all passages are blocked.

10. The valve with the tandem outer spool unloads the pump while in the outer position.

11. The advantage is that actuator lines do not have a build up in pressure when the P passage is blocked as in the closed center condition which controls piston rod duft.

TEST ANSWERS

12. A spring located at each end of the three-position valve will normally keep the valve centered. After being actuated, the valve may not recenter due to excessive flow rate but using hydraulic pressure in a pilot valve will recenter the spool.

13. A choke control is a needle valve which is positioned in the pilot line. It limits the pilot flow rate to the valve and therefore its shifting speed.

INTRODUCTION TO HYDRAULICS

UNIT VI

PRESSURE CONTROL VALVES

PRESSURE CONTROL VALVES

UNIT VI

OBJECTIVE

After completing this unit, the student should be able to determine the difference between types of pressure control valves and which one to use in a circuit. This knowledge will be shown by completing the end of chapter exercise, lab procedures, lab checkout activity and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Give an example of why a sequence valve would be used in a circuit.
2. Give an example of why a counterbalance valve would be used in a circuit.
3. Describe how a pressure reducing valve senses an over pressure.
4. Tell why a pressure control valve might have a drain.
5. Explain how an unloading valve will prevent a waste of horsepower once an accumulator is charged.
6. Explain how a remotely operated counterbalance valve prevents or cancels out weight on a cylinder.
7. Explain how an 8:1 brake valve functions in a circuit.
8. Describe how reverse flow is passed through a pressure control valve.
9. Demonstrate the ability to
   - A. Repair sequence valves.
   - B. Construct counterbalance valves.
   - C. Troubleshoot pressure reducing valves.
   - D. Construct unloading valves.
   - E. Troubleshoot two-way piloted bypass pressure control valves.

PRESSURE CONTROL VALVES

UNIT VI

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with unit procedure sheets, text, and lab manual.

  C. Make transparencies.

  D. Discuss unit objective, specific objectives, and procedure sheets.

  E. Discuss chapter 9 and exercise.

  F. Discuss labs ML4 - A, B, C, D, E, and checkout activities.

  G. Assist students with chapter exercises.

  H. Assist student with labs ML4 - A, B, C, D, E, and checkout activities.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheet.

  C. Take test.

UNIT VI

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheets.

   C. Text.

   D. Videotape (optional).

   E. Lab Manual.

   F. Test.

   G. Answers to chapter exercises.

   H. Answers to test.

II. References

A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.

B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrual, Inc., 1983.

C. Anderson, Norman A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.

D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.

E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

PRESSURE CONTROL VALVES

UNIT VI

PROCEDURE SHEET

____1.	Study	Chapter 9, Pressure Control Valves, in your text.
____2.	Watch	IHT Videotape Supplement for Chapter 9.
____3.	Do	Exercise for Chapter 9 in your text.
____4.	Stop	Have the instructor evaluate the chapter exercise before you continue.
____5.	Study	Lab ML 4-A, Sequence Valve, in your lab manual.
____6.	Do	Lab ML 4-A
____7.	Stop	Have the instructor rate your performance for Lab ML 4-A before you continue.
____8.	Complete	Checkout Activities for Lab ML 4-A.
____9.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 4-A.
____10.	Study	Lab ML 4-B, Counterbalance Valve, in your lab manual.
____11.	Do	Lab ML 4-B
____12.	Stop	Have the instructor rate your performance for Lab ML 4-B before you continue.
____13.	Complete	Checkout Activities for Lab ML 4-B.
____14.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 4-B.
____15.	Study	Lab ML 4-C, Pressure Reducing Valve, in you lab manual.
____16.	Do	Lab ML 4-C
____17.	Stop	Have the instructor rate your performance for Lab ML 4-C before you continue.
____18.	Complete	Checkout Activities for Lab ML 4-C.
____19.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 4-C.

PROCEDURE SHEET

____20.	Study	Lab ML 4-D, Unloading Valve, in your lab manual.
____21.	Do	Lab ML 4-D.
____22.	Stop	Have the instructor rate your performance for Lab ML 4-D before you continue.
____23.	Complete	Checkout Activities for Lab ML 4-D.
____24.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 4-D.
____25.	Study	Lab ML 4-E, Failed Valve Inspection, in your lab manual.
____26.	Do	Lab ML 4-E.
____27.	Stop	Have the instructor rate your performance for Lab ML 4-E before you continue.
____28.	Complete	Checkout Activities for Lab ML 4-E.
____29.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 4-E.
____30.	Review	Chapter 9, Pressure Control Valves, in your text and Labs ML 4A-E.
____31.	Take	Hydraulics Test #6.
____32.	Stop	Have your instructor evaluate Hydraulics Test #6. If your instructor is satisfied with your performance, continue on to Unit VII. Otherwise review the areas suggested by your instructor and repeat Steps 31 and 32.

PRESSURE CONTROL VALVES

UNIT VI

TEST

NAME____SCORE____________

1. Give an example of why a sequence valve would be used in a circuit.

2. Give an example of why a counterbalance valve would be used in a circuit.

3. Describe how a pressure reducing valve senses an over pressure.

4. Tell why a pressure control valve might have a drain.

TEST

5. Explain how an unloading valve could prevent a waste of horsepower.

6. Explain how a remotely operated counterbalance valve prevents or cancels out weight on a cylinder.

7. Explain how an 8:1 brake valve functions in a circuit.

8. Describe how reverse flow is passed through a pressure control valve.

9. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

PRESSURE CONTROL VALVES

UNIT VI

TEST ANSWERS

1. A sequence valve is positioned in a leg of a circuit ahead of the operation that is to occur second.
2. A counterbalance valve can be used to retard the spinning motion of a weight attached to a motor shaft.
3. Through a passage downstream from the cylinder over pressure is reused and directed back to close the spool. After the over pressure has dropped the pressure on the spool drops and allows the spool to move back to the normally open position.
4. Fluid leaks into the passage above the spool which could prevent the spool from being activated. A drain prevents this.
5. This valve is a normally closed valve which senses a full situation and opens to allow a minimum pressure and closes when this is an unfull situation.
6. As the load on a cylinder drops off, the counterbalance valve will open and cause the pressure to catch up.
7. When the pressure in the main cylinder is 8, the pressure in the pilot valve will be 1. When the pressure in the pilot passage exceeds 1, the pilot valve activates and moves the spool to decrease the flow and hence the pressure. When the pressure is below 1 in the pilot passage the pilot valve closes again to allow the pressure to come back to 8 and 1.
8. Reverse flow is passed through a pressure control valve by using a check valve.

INTRODUCTION TO HYDRAULICS

UNIT VII

PILOT OPERATED CONTROLS

PILOT OPERATED CONTROLS

UNIT VII

OBJECTIVE

After completing this unit, the student should be able to determine which kind of pilot operated pressure control valves will be needed for different situations. This knowledge will be shown by completing the end of chapter exercise, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to:

1. Discuss why a direct operated relief valve would be needed in a circuit.
2. Explain how a pilot valve in a relief valve functions.
3. Tell what is meant by releasing pilot pressure on a relief valve.
4. Explain how a differential unloading relief valve works.
5. Demonstrate the ability to
    A. Repair direct acting relief valves.
    B. Maintain pilot operated relief valves.
    C. Determine if relief valves (safety or pressure limiting bypass valves) are reusable.
    D. Learn how deceleration circuits work.
    E. Determine sources of system leakage and eliminate undesirable circuit operation.
    F. Use the pressure reducing valve in a hydraulic system subcircuit.
    G. Determine how sequencing is done in hydraulic systems.
    H. Troubleshoot malfunctions of the pilot operated relief valve.
    I. Use on-off function in controlling system pressure with vented pilot operated relief valves.

J. Control hydraulic systems with multiple pressures using the pilot operated relief valves.

K. Use counterbalance control of heavy or overrunning loads in hydraulic circuits.

L. Learn unloading valve variations and limitations.

M. Use direct acting relief valves in a hydraulic circuit.

N. Determine the use of pilot operated relief valves.

O. Apply unloading relief valves to accumulator circuits.

P. Use solenoid operated directional control valves/electromechanical controls with relays in a actuator reversing circuit.

Q. Install limit switches in a control circuits.

R. Use and troubleshoot the differential pressure switch.

PILOT OPERATED CONTROLS

UNIT VII

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide student with objective sheet.

   B. Provide students with unit procedure sheets, text, and lab manual.

   C. Make transparencies.

   D. Discuss unit objective, specific objectives, and procedure sheets.

   E. Discuss chapter 10 and exercise.

   F. Discuss labs ML5 - A, B, C, and labs TC4 - A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist student with labs ML5 - A, B, C, and labs TC4 - A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

UNIT IV

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Text.

  D. Videotape (optional).

  E. Lab Manual.

  F. Test.

  G. Answers to chapter exercises.

  H. Answers to test.

II. References

A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.

B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.

C. Anderson, Normand A., Instrumentation for Process Measurement and Contro., Rachor, Pennsylvania, Chilton Ca., 1980.

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E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

PILOT OPERATED CONTROLS

UNIT VII

PROCEDURE SHEET

_____1. Study Chapter 10, Pilot Operated Pressure Controls, in your text.

_____2. Watch IHT Videotape Supplement for Chapter 10.

_____3. Do Exercise for Chapter 10 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab ML 5-A, Direct Acting Relief, in your lab manual.

_____6. Do Lab ML 5-A

_____7. Stop Have the instructor rate your performance for Lab ML 5-A before you continue.

_____8. Complete Checkout Activities for Lab ML 5-A.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab ML 5-A.

____10. Study Lab ML 5-B, Pilot Operated Relief, in your lab manual.

____11. Do Lab ML 5-B.

____12. Stop Have the instructor rate your performance for Lab ML 5-B before you continue.

____13. Complete Checkout Activities for Lab ML 5-B.

____14. Stop Have the instructor evaluate the Checkout Activities for Lab ML 5-B.

____15. Study Lab ML 5-C, Failed Valve Inspection, in your lab manual.

____16. Do Lab ML 5-C.

____17. Stop Have the instructor rate your performance for Lab ML 5-C before you continue.

____18. Complete Checkout Activities for Lab ML 5-C.

____19. Stop Have the instructor evaluate the Checkout Activities for Lab ML 5-C.

PROCEDURE SHEET

____20. Study Lab TC 4-A, Cylinder Rapid Advance, Decel and Slow Feed, in your lab manual.

____21. Do Lab TC 4-A

____22. Stop Have the instructor rate your performance for Lab TC 4-A before you continue.

____23. Complete Checkout Activities for Lab TC 4-A.

____24. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-A.

____25. Study Lab TC 4-B, Closed Center Actuator Line Build-Up and Testing for Cylinder Leakage, in your lab manual.

____26. Do Lab TC 4-B

____27. Stop Have the instructor rate your performance for Lab TC 4-B before you continue.

____28. Complete Checkout Activities for Lab TC 4-B.

____29. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-B.

____30. Study Lab TC 4-C, Cylinder Clamp @ Reduced Pressure, in your lab manual.

____31. Do Lab TC 4-C

____32. Stop Have the instructor rate your performance for Lab TC 4-C before you continue.

____33. Complete Checkout Activities for Lab TC 4-C.

____34. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-C.

____35. Study Lab TC 4-D, Cylinder Sequencing, in your lab manual.

____36. Do Lab TC 4-D

____37. Stop Have the instructor rate your performance for Lab TC 4-D before you continue.

____38. Complete Checkout Activities for Lab TC 4-D.

____39. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-D.

PROCEDURE SHEET

____40. Study Lab TC 4-E, Pilot Operated Relief Remote Controlled, in your lab manual.

____41. Do Lab TC 4-E

____42. Stop Have the instructor rate your performance for Lab TC 4-E before you continue.

____43. Complete Checkout Activities for Lab TC 4-E.

____44. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-E.

____45. Study Lab TC 4-F, Vented Pilot Operated Relief, in lab manual.

____46. Do Lab TC 4-F

____47. Stop Have the instructor rate your performance for Lab TC 4-F before you continue.

____48. Complete Checkout Activities for Lab TC 4-F.

____49. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-F.

____50. Study Lab TC 4-G, Three System Pressure Control, in your lab manual.

____51. Do Lab TC 4-G

____52. Stop Have the instructor rate your performance for Lab TC 4-G before you continue.

____53. Complete Checkout Activities for Lab TC 4-G.

____54. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-G.

____55. Study Lab TC 4-H, Remote and Direct Counterbalance, in your lab manual.

____56. Do Lab TC 4-H

____57. Stop Have the instructor rate your performance for Lab TC 4-H before you continue.

____58. Complete Checkout Activities for Lab TC 4-H.

____59. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-H.

PROCEDURES SHEET

____60. Study Lab TC 4-I, Unloader Valve, in your lab manual.

____61. Do Lab TC 4-I.

____62. Stop Have the instructor rate your performance for Lab TC 4-I before you continue.

____63. Complete Checkout Activities for Lab TC 4-I.

____64. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-I.

____65. Study Lab TC 4-J, Direct Acting Relief Performance, in your lab manual.

____66. Do Lab TC 4-J.

____67. Stop Have the instructor rate your performance for Lab TC 4-J before you continue.

____68. Study Lab TC 4-K, Pilot Operated Relief Performance, in your lab manual.

____69. Do Lab TC 4-K.

____70. Stop Have the instructor rate your performance for Lab TC 4-K before you continue.

____71. Complete Checkout Activities for Lab TC 4-K.

____72. Stop Have the instructor evaluate the Checkout Activities for Lab TC 4-K.

____73. Study Lab TC 4-L, Differential Unloading Relief, in your lab manual.

____74. Do Lab TC 4-L.

____75. Stop Have the instructor rate your performance for Lab TC 4-L before you continue.

____76. Complete Checkout Activities for Lab TC 4-L.

____77. Stop Have the instructor evaluate the Checkout Activities for Lab 4-L.

____78. Study Lab TC 4-M, Electro-Mechanical Control of Directional Control Valves, in your lab manual.

____79. Do Lab TC 4-M.

PROCEDURES SHEET

____80. Stop — Have the instructor rate your performance for Lab TC 4-M before you continue.

____81. Complete — Checkout ACtivities for Lab TC 4-M.

____82. Stop — Have the instructor evaluate the Checkout Activities for Lab TC 4-M.

____83. Study — Lab TC 4-N, E.M. Control with Limit Switches, in your lab manual.

____84. Do — Lab TC 4-N.

____85. Stop — Have the instructor rate your performance for Lab TC 4-N before you continue.

____86. Complete — Checkout Activities for Lab TC 4-N.

____87. Stop — Have the instructor evaluate the Checkout Activities for Lab TC 4-N.

____88. Study — Lab TC 4-O, E.M. Control with Pressure Switch, in your lab manual.

____89. Do — Lab TC 4-O.

____90. Stop — Have the instructor rate your performance for Lab TC 4-O before you continue.

____91. Complete — Checkout Activities for Lab TC 4-O.

____92. Stop — Have the instructor evaluate the Checkout Activities for Lab TC 4-O.

____93. Review — Chapter 10, Pilot Operated Pressure Controls, and Labs ML 5A-C and TC 4A-O.

____94. Take — Hydraulic Test #7.

____95. Stop — Have your instructor evaluate your performance for this test. If you scored 80 percent or more, continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

PILOT OPERATED CONTROLS

UNIT VII

TEST

NAME____SCORE___________

1. Discuss why a direct operated relief valve would be needed in a circuit.

2. Explain how a pilot valve in a relief valve works.

3. Tell what is meant by releasing pilot pressure on a relief valve.

4. Explain how a differential unloading relief valve works.

5. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

PILOT OPERATED CONTROLS

UNIT VII

TEST ANSWERS

1. As flow in a circuit increases to its set flow rate, a relief valve begins to open at a lower pressure. As the flow continues to increase, the relief valve continues to open until the system reaches its maximum flow rate. At the moment there is over pressure the relief valve senses this and shuts down the flow rate.

2. The pilot valve is preset to maintain a certain pressure on a spool. If the flow pressure on the other section of the spool exceeds the pilot pressure, the pilot relief valve opens and releases its pressure allowing the spool to move which allows the flow to be diverted to tank. When the flow pressure drops back to its set point the valves close.

3. Releasing pilot pressure refers to venting a relief valve to release fluid pressure biasing the main spool of the pilot operated valve.

4. This valve has a cluck valve which closes when the pilot valve opens. At that time flow is going to tank. This will continue until the accumulator discharge to a lower pressure at which time the check valve opens and the pilot valve close.

INTRODUCTION TO HYDRAULICS

Unit VIII

Hydraulic Pumps and Motors

HYDRAULIC PUMPS AND MOTORS

UNIT VIII

OBJECTIVE

After completing this unit, the student should be able to differentiate between the different hydraulic pumps and motors. This knowledge will be shown by completing end-of-chapter exercises, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Discuss how a vane pump works.
2. Discuss how a variable volume vane pump works.
3. Explain the difference in external, internal and genotor gear pumps.
4. Explain how incoming fluid is separated from discharge fluid in a bent-axis and a radial piston pump.
5. Give the overall efficiency for a hydraulic pump.
6. Determine which of constant volume, hi-lo, or pressure compensated system is the most efficient.
7. Discuss how system working pressure and tank line pressure affect a vane motor.
8. Differentiate between external, internal, and gerotor motors.
9. List the parts and function of a piston motor.
10. Explain how to calculate the torque rating.
11. Discuss how motor shaft speed is calculated.
12. Discuss how motor shaft speed would decrease in a motor.
13. Explain how to cause a motor to cavitate.
14. Differentiate between open loop and closed loop hydrostatic drive.

SPECIFIC OBJECTIVES

15. Demonstrate the ability to

    A. Determine repair feasibility of gear pumps and pressure compensated vane pumps.

    B. Recognize whether parts on piston pumps can be saved, reused or rejected.

    C. Overhaul and test procedures for high torque, low speed hydraulic motors.

    D. Use the portable hydraulic tester and gages.

    E. Find the trouble in a pump and motor and determine if repairable, using portable hydraulic testor and gage.

    F. Determine if failed pump or motor are repairable.

    G. Determine control of a hydraulic motor by meter-in flow control.

    H. Determine control of a hydraulic motor by meter-out flow control.

    I. Understand the application of the hydraulically actuated brake valve.

    J. Prevent cavitation in hydraulic motor circuits.

    K. Apply techniques to obtain successful circuit operations.

    L. Recognize, apply and set the cross-over relief valves.

    M. Construct variations combining over-run limiting with cushioning and stopping of hydraulic motors.

    N. Determine the overall efficiency of hydraulic circuits.

    O. Test and adjust pressure compensated pump operations.

HYDRAULIC PUMPS AND MOTORS

UNIT VIII

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with unit procedure sheets, text, and lab manual.

   C. Make transparencies.

   D. Discuss unit objective, specific objectives, and procedure sheets,

   E. Discuss chapter 11 and exercise.

   F. Discuss labs ML6 - A, B, C, D, E, F, and labs TC5 - A, B, C, D, E, F, G, H, I, and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist student with labs ML6 - A, B, C, D, E, F, and labs TC5 - A, B, C, D, E, F, G, H, I, and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

UNIT VIII

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Text.

  D. Videotape (optional).

  E. Lab Manual.

  F. Test.

  G. Answers to chapter exercises.

  H. Answers to test.

II. References

A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.

B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.

C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.

D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.

E. Sullivan, James A., Fluid Power, Restor, Virginia, Reston Publishing Co., 1982.

F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

HYDRAULIC PUMPS AND MOTORS

UNIT VIII

PROCEDURE SHEET

_____1. Study Chapters 11, *Hydraulic Pumps*, and 12, *Hydraulic Motors*, in your text.

_____2. Watch IHT Videotape Supplement for Chapters 11 and 12.

_____3. Do Exercise for Chapters 11 and 12 in your text.

_____4. Stop Have the instructor evaluate the chapter exercises before you continue.

_____5. Study Lab ML 6-A, *Gear Lane*, in your lab manual.

_____6. Do Lab ML 6-A.

_____7. Stop Have the instructor rate your performance for Lab ML 6-A before you continue.

_____8. Complete Checkout Activities for Lab ML 6-A.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab ML 6-A.

_____10. Study Lab ML 6-B, *Pressure Compensated Vane Pumps*, Variable Vol, in your lab manual, Parts I-IV.

_____11. Do Lab ML 6-B, Parts I-IV.

_____12. Stop Have the instructor rate your performance for Lab ML 6-B.

_____13. Complete Checkout Activities for Lab ML 6-B, Parts I-IV.

_____14. Stop Have the instructor evaluate the Checkout Activities for Lab ML 6-B.

_____15. Study Lab ML 6-C, *Piston Pumps*, in your lab manual, Parts I-IV.

_____16. Do Lab ML 6-C, Parts I-IV.

_____17. Stop Have the instructor rate your performance for Lab ML 6-C.

_____18. Complete Checkout Activities for Lab ML 6-C, Parts I, II, & IV.

_____19. Stop Have the instructor evaluate the Checkout Activities for Lab ML 6-C.

PROCEDURE SHEET

____20. Study Lab ML 6-D, High Torque, Low Speed Hydraulic Motor, in your lab manual.

____21. Do Lab ML 6-D

____22. Stop Have the instructor rate your performance for Lab ML 6-D.

____23. Complete Checkout Activities for Lab ML 6-D.

____24. Stop Have the instructor evaluate the Checkout Activities for Lab ML 6-D.

____25. Study Lab ML 6-E, Portable Hydraulic Tester and Gages, in your lab manual.

____26. Do Lab ML 6-E

____27. Stop Have the instructor rate your performance for Lab ML 6-E.

____28. Complete Checkout Activities for Lab ML 6-E.

____29. Stop Have the instructor evaluate the Checkout Activities for Lab ML 6-E.

____30. Study Lab ML 6-F, Failed Pump and Motor Inspection, in your lab manual.

____31. Do Lab ML 6-F

____32. Stop Have the instructor rate your performance for Lab ML 6-F.

____33. Complete Checkout Activities for Lab ML 6-F.

____34. Stop Have the instructor evaluate the Checkout Activities for Lab ML 6-F.

____35. Study Lab TC 5-A, Meter-in Flow Control with Hyd. Motor, in lab manual.

____36. Do Lab TC 5-A

____37. Stop Have the instructor rate your performance for Lab TC 5-A.

____38. Complete Checkout Activities for Lab TC 5-A.

____39. Stop Have the instructor evaluate the Checkout Activities for Lab TC 5-A.

PROCEDURE SHEET

____40.	Study	Lab TC 5-B, Meter-out Flow Control with Hyd. Motor, in lab manual.
____41.	Do	Lab TC 5-B
____42.	Stop	Have the instructor rate your performance for Lab TC 5-B.
____43.	Complete	Checkout Activities for Lab TC 5-B.
____44.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-B.
____45.	Study	Lab TC 5-C, Brake Valve Control of Hyd. Motors, in your lab manual.
____46.	Do	Lab TC 5-C
____47.	Stop	Have the instructor rate your performance for Lab TC 5-C.
____48.	Complete	Checkout Activities for Lab TC 5-C.
____49.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-C.
____50.	Study	Lab TC 5-D, Cavitation Prevention in Hyd. Motors, in lab manual.
____51.	Do	Lab TC 5-D
____52.	Stop	Have the instructor rate your performance for Lab TC 5-D.
____53.	Complete	Checkout Activities for Lab TC 5-D.
____54.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-D.
____55.	Study	Lab TC 5-E, Braking Relief Control of Hyd. Motors, in lab manual.
____56.	Do	Lab TC 5-E
____57.	Stop	Have the instructor rate your performance for Lab TC 5-E.
____58.	Complete	Checkout Activities for Lab TC 5-E.
____59.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-E.

PROCEDURE SHEET

____60.	Study	Lab TC 5-F, Cross-over Relief (Dual), in your lab manual.
____61.	Do	Lab TC 5-F
____62.	Stop	Have the instructor rate your performance for Lab TC 5-F.
____63.	Complete	Checkout Activities for Lab TC 5-F.
____64.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-F.
____65.	Study	Lab TC 5-G, Counterbalance Motor Control Audiovisual Presentation Hydraulic Circuit Efficiency, in your lab manual.
____66.	Do	Lab TC 5-G
____67.	Stop	Have the instructor rate your performance for Lab TC 5-G.
____68.	Complete	Checkout Activities for Lab TC 5-G.
____69.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-G.
____70.	Study	Lab TC 5-H, Hydraulic Circuit Efficiency, in your lab manual.
____71.	Do	Lab TC 5-H
____72.	Stop	Have the instructor rate your performance for Lab TC 5-H.
____73.	Complete	Checkout Activities for Lab TC 5-H.
____74.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-H.
____75.	Study	Lab TC 5-I, Pressure Compensated Pump Operation, in your lab manual.
____76.	Do	Lab TC 5-I
____77.	Stop	Have the instructor rate your performance for Lab TC 5-I.
____78.	Complete	Checkout Activities for Lab TC 5-I.
____79.	Stop	Have the instructor evaluate the Checkout Activities for Lab TC 5-I.

PROCEDURE SHEET

____80. Review Chapters 11 and 12, Hydraulic Pumps and Motors, Lab ML 6-A thru F and TCSA-SI.

____81. Take Hydraulics Test #8.

____82. Stop Have your instructor evaluate your performance for this test. If you scored 80 percent or more, continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

HYDRAULIC PUMPS AND MOTORS

UNIT VIII

TEST

NAME____SCORE__________

1. Discuss how a vane pump works.

2. Discuss how a variable volume vane pump works.

3. Explain the difference in external, internal, and gerotor gear pumps.

4. Explain how incoming fluid is separated from discharge fluid in a bent-axis and a radial piston pump.

TEST

5. Give the overall efficiency for a hydraulic pump.

6. Determine which of constant volume, hi-lo, or pressure compensated systems is the most efficient.

7. Discuss how system working pressure and tank line pressure affect a vane motor.

8. Differentiate between external, internal, and gerotor gear motors.

9. List the parts and function of the parts of a piston motor.

TEST

10. Explain how to calculate the torque rating.

11. Discuss how motor shaft speed is calculated.

12. Discuss how motor shaft speed would decrease in a motor.

13. Explain how to cause a motor to cavitate.

14. Differentiate between open loop and closed loop hydrostatic drive.

15. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

HYDRAULIC PUMPS AND MOTORS

UNIT VIII

TEST ANSWERS

1. As the offset rotor of a vane pump turns, adjustable vanes take in fluid from the inlet in an increasing volume cavity and then release the fluid in a decreasing cavity to the outlet.

2. Variable-volume vane pumps work like the vane pumps except that the cam ring is free to move and is adjustable. This adjusting increases the variable-volume vanes.

3. External gear pumps have teeth on the circumference of their gears. Internal gear pumps have one gear inside the other. The gerotor pump is an internal gear pump that has one less tooth on the inner gear than the outer gear.

4. In the bent-axis piston pump incoming fluid is separated from discharge fluid by means of a part plate while in the radial piston pump fluid enters and is discharged thru the valve block in the center of the pump.

5. The overall efficiency is obtained by dividing the hydraulic output horsepower by the prime mover horsepower.

6. Of the three, the compensated system is most efficient because the relief valve is not needed.

7. System working pressure is at the inlet and tank line pressure is at the outlet which could result in side loading the shaft if the inner contour weren't changed.

8. In the external gear motor both gears have teeth on their circumferences. In the internal gear motor one gear is inside another gear. A guoter is an example of an internal gear motor with one more tooth on the outer gear than the inner gear.

9. Pistons fit inside a cylinder and the swashplate is at an angle and acts as a surface on which the shoe side of the piston rides. The piston shoes are held in place by the swash plate and bia spring. The part plate separates incoming from discharging fluid.

10. After determining the desired maximum system pressure the required output torque is divided by the operating pressure to give the motor torque rating.

TEST ANSWERS

11. Once the motor size is known, a pump with the appropriate flow rate is selected and the flow rate is divided by the motor displacement to give shaft speed.

12. One way for motor shaft speed to decrease is to have more fluid drain as torque and pressure requirements increase.

13. A motor will cavitate any time a sufficient supply of fluid is not received at the inlet for example during braking.

14. An open loop hydrostatic drive has the motor outlet connected to the tank. A closed loop hydrostatic drive has motor inlet connected to the pump outlet and motor outlet connected to pump inlet.

INTRODUCTION TO HYDRAULICS

UNIT IX

FLUIDS, RESERVOIRS, COOLERS AND FILTERS

FLUIDS, RESERVOIRS, COOLERS AND FILTERS

UNIT IX

OBJECTIVES

After completing this unit, the student should be able to distinguish between types of hydraulic fluids, explain the function of reservoirs and coolers, discuss how different kinds of dirt affect filters and give advantages and disadvantages of filter types. This knowledge will be shown by completing the end-of-chapter exercise, lab sheets, checkpoint activities, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Name five petroleum base hydraulic fluids.
2. Name four fire resistant hydraulic fluids.
3. Explain the function of a reservoir.
4. Describe how two types of coolers function.
5. Explain four functions of hydraulic fluid.
6. Describe how the three sizes of dirt interfere with hydraulic fluid.
7. Tell what the function of a mechanical filter is.
8. List three ways dirt gets into a system.
9. List advantages and disadvantages of sump, suction, pressure, and return line filters.
10. Describe how a filter bypass valve works.
11. Describe how a filter indicator shows a filter is dirty and needs changing.
12. Demonstrate the ability to
    - A. Service sump strainers.
    - B. Recognize types and styles of suction filters.
    - C. Install return line filters.
    - D. Troubleshoot pressure filters.

SPECIFIC OBJECTIVES

E. Maintain hydraulic reservoirs, heaters and coolers.

F. Apply fluid analysis procedures to a hydraulic system.

G. Operate a portable filter cart.

FLUIDS, RESERVOIRS, COOLERS, AND FILTERS

UNIT IX

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with unit procedure sheets, text, and lab manual.

   C. Make transparencies.

   D. Discuss unit objective, specific objectives, and procedure sheets.

   E. Discuss chapter 13 and exercise.

   F. Discuss labs ML7 - A, B, C, D, E, F, G, and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist student with labs ML7 - A, B, C, D, E, F, G, and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete sheet.

   C. Take test.

UNIT IX

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Text.
- D. Videotape (optional).
- E. Lab Manual.
- F. Test.
- G. Answers to chapter exercises.
- H. Answers to test.

II. References

- A. Industrial Hydraulic Technology, Cleveland, Ohio Parker - Hannifin Corp., 1982.
- B. Perkins, Don Industrial Technology Trainer Laboratory Manual, Applied Fluid Power, Vol. I and Vol. II Hydraulic - Electromechanical. Clarksville, Indiana, Amatrol Inc., 1983.
- C. Anderson, Normand A., Instrumentation for Process Measurement and Control, Rachor, Pennsylvania, Chilton Ca., 1980.
- D. Practical Guide to Fluid Power, New York, New York, Theodore Audel & Co., 1970.
- E. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.
- F. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extension Service, UT, 1983.

FLUIDS, RESERVOIRS, COOLERS AND FILTERS

UNIT IX

PROCEDURE SHEET

_____1. Study Chapter 13, Fluids, Reservoirs, Coolers and Filters, in your text.

_____2. Watch IHT Videotape Supplement for Chapter 13.

_____3. Do Exercise for Chapter 13 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab ML 7-A, Suction Strainers, in your lab manual.

_____6. Do Lab ML 7-A.

_____7. Stop Have the instructor rate your performance for Lab ML 7-A before you continue.

_____8. Complete Checkout Activities for Lab ML 7-A.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab ML 7-A.

_____10. Study Lab ML 7-B, Suction Filters, in your lab manual.

_____11. Do Lab ML 7-B.

_____12. Stop Have the instructor rate your performance for Lab ML 7-B.

_____13. Complete Checkout Activities for Lab ML 7-B.

_____14. Stop Have the instructor evaluate the Checkout Activities for Lab ML 7-B.

_____15. Study Lab ML 7-C, Return Line Filters, in your lab manual.

_____16. Do Lab ML 7-C.

_____17. Stop Have the instructor rate your performance for Lab ML 7-C.

_____18. Complete Checkout Activities for Lab ML 7-C.

_____19. Stop Have the instructor evaluate the Checkout Activities for Lab ML 7-C.

PROCEDURE SHEET

_____20.	Study	Lab ML 7-D, Pressure Filters, in your lab manual.
_____21.	Do	Lab ML 7-D.
_____22.	Stop	Have the instructor rate your performance for Lab ML 7-D.
_____23.	Complete	Checkout Activities for Lab ML 7-D.
_____24.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 7-D.
_____25.	Study	Lab ML 7-E, Hydraulic Reservoirs, Heaters & Coolers, in your lab manual.
_____26.	Do	Lab ML 7-E.
_____27.	Stop	Have the instructor rate your performance for Lab ML 7-E.
_____28.	Complete	Checkout Activities for Lab ML 7-E.
_____29.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 7-E.
_____30.	Study	Lab ML 7-F, Fluid Analysis & Fluids, in your lab manual.
_____31.	Do	Lab ML 7-F.
_____32.	Stop	Have the instructor rate your performance for Lab ML 7-F.
_____33.	Complete	Checkout Activities for Lab ML 7-F.
_____34.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 7-F.
_____35.	Study	Lab ML 7-G, Portable Filter Cart, in your lab manual.
_____36.	Do	Lab ML 7-G.
_____37.	Stop	Have the instructor rate your performance for Lab ML 7-G.
_____38.	Complete	Checkout Activities for Lab ML 7-G.
_____39.	Stop	Have the instructor evaluate the Checkout Activities for Lab ML 7-G.

PROCEDURE SHEET

____40. Review Chapter 13, Fluids, Reservoirs, Coolers and Filters, and Lab ML-7A through G.

____41. Take Hydraulics Test #9.

____42. Stop Have your instructor evaluate Hydraulics Test #9. If your instructor is satisfied with your performance, CONGRATULATIONS! You have completed this course. Otherwise review the areas suggested by your instructor and repeat Steps 41 and 42.

FLUIDS, RESERVOIRS, COOLERS AND FILTERS

UNIT IX

TEST

NAME ______________________________ SCORE ____________

1. Name five petroleum base hydraulic fluids.

   a.

   b.

   c.

   d.

   e.

2. Name four fire resistant hydraulic fluids.

   a.

   b.

   c.

   d.

3. Explain the function of a reservoir.

4. Describe how two types of coolers function.

TEST

5. Explain four functions of hydraulic fluids.

a.

b.

c.

d.

6. Describe how the three sizes of dirt interfere with hydraulic fluids.

7. Tell what the function of a mechanical filter is.

8. List three ways dirt gets into a system.

a.

b.

c.

TEST

9. List advantages and disadvantages of sump, suction, pressure and return line filters.

10. Describe how a filter bypass valve works.

11. Describe how a filter indicator shows a filter is dirty and needs changing.

12. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more you have successfully completed this section. If additional study is required, ask your instructor about study requirements and possible retesting.

FLUIDS, RESERVOIRS, COOLERS AND FILTERS

UNIT IX

TEST QUESTIONS

1. Viscosity improvers, oxidation inhibitors, corrosion inhibitors, external pressure/anti-wear additives, anti-foam additives.

2 Oil-in-water emulsion, water-in-oil emulsion, water glycol, synthetic.

3. It acts as a container due to its construction; it acts as a cooler because of the heat absorbing material; it allows large dirt to settle out due to the quiet zone and air to rise to the surface because of the quiet zone.

4. Air cooling is accomplished by allowing cool air to pass through a radiator which contains the fluid flows. The water cooler pass hydraulic fluid around tubes containing cool water.

5. Hydraulic fluid acts like a medium to transfer energy; to lubricate internal running parts; transfer heat, and to seal clearances between close fitting seals.

6. Fine dirt can accumulate in clearances especially where there isn't frequent operation and obstruct lubricative flow. Dirt the size of a clearance breaks down a fluid lubricative filter. Large dirt interferes with lubrication by collecting at clearances and blocking flow.

7. The function of a mechanical filter is to remove dirt from hydraulic fluid.

8. Dirt can be built into a system, generated in a system, or added to a system.

9.

Filter	Disadvantages	Advantages
Scump	--Hard to service --Hard to tell if dirty --May block fluid flow --Doesn't protect downstream components	--Protect the pump from dirt --Inexpensive
Suction	--May stain pump --Doesn't protect downstream components	--Protects pump from dirt --Indicator to change --Can be services without changing
Pressure	--High pressure construction --Due to pressure dirt can be forced through	--Filters very fine --Protects component from upstream particles

TEST QUESTIONS

Filter	Disadvantages	Advantages
Return line	--No protection for components --Flow surges have to be considered --Components affected by back pressure	--Catches dirt before it enters reservoir --No high pressure construction --Good fine filter because of pressure

10. A spring loaded valve senses the difference in pressure between clear and dirty fluid. The dirtier the fluid, the more pressure required to push fluid through a filter.

11. An indicator attached to a helix through a spring loaded valve rotates due to the movement of the valve when the filter is dirty.

INTRODUCTION TO PNEUMATICS

UNIT I

FORCE TRANSMISSION

FORCE TRANSMISSION

UNIT I

OBJECTIVE

After completing this unit, the student should be able to explain how fluid pressure is transmitted and intensified, describe the difference between gage and atmospheric pressure and describe how the two gages function. This knowledge will be shown by completing end-of-chapter exercises, lab procedures, lab checkout activities, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. List three forms of power transmission.
2. Define fluid power.
3. Name four advantages compressed air components may have.
4. Explain how a force is transmitted through a fluid.
5. Describe how a mechanical force can be multiplied.
6. State how an intensifier functions.
7. Explain the difference between gage pressure and atmospheric pressure.
8. Explain how the two common pressure gages function.
9. Describe how the inclined manometer works.
10. Explain PSIA and PSIG.
11. Calculate absolute pressure using a vacuum gage.
12. Demonstrate the ability to
    - A. Use compressed air and fluid power transmission by a gas.
    - B. Provide a safe invironment when working with compressed air/gas.
    - C. Measure pressure with gages/manometers.
    - D. Recognize the kind of pressure being measured.

FORCE TRANSMISSION

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure sheets, test, and lab manual.

   C. Make transparencies.

   D. Discuss unit objectives, specific objectives, and procedure sheets.

   E. Discuss chapter 1 and 2 and exercises.

   F. Discuss labs L1-L4 and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist students with labs L1-L4 and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

FORCE TRANSMISSION

UNIT I

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Text.
- D. Lab manual.
- E. Test.
- F. Answers to chapter exercises.
- G. Answers to test.

II. References

- A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.
- B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.
- C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.
- D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.
- E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

FORCE TRANSMISSION

UNIT I

PROCEDURE SHEET

_____1. Study Chapters 1, Evolution of Compressed Air, and 2, Force Transmission Thru a Fluid, in your text.

_____2. Watch Videotape Supplement for Chapter 1.

_____3. Do Exercises for Chapters 1 and 2 in your text.

_____4. Stop Have the instructor evaluate the chapter exercises before you continue.

_____5. Study Lab L-1, Applications/Advantages, in your lab manual.

_____6. Do Lab L-1.

_____7. Stop Have the instructor rate your performance for Lab L-1 before you continue.

_____8. Complete Checkout Activities for Lab L-1.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab L-1.

____10. Study Lab L-2, Safety & Compressed Air, in your lab manual.

____11. Do Lab L-2.

____12. Stop Have the instructor rate your performance for Lab L-2 before you continue.

____13. Complete Checkout Activities for Lab L-2.

____14. Stop Have the instructor evaluate the Checkout Activities for Lab L-2.

____15. Study Lab L-3, Pressure Measurement (Gages/Manometers), in your lab manual.

____16. Do Lab L-3.

____17. Stop Have the instructor rate your performance for Lab L-3 before you continue.

____18. Complete Checkout Activities for Lab L-3.

____19. Stop Have the instructor evaluate the Checkout Activities for Lab L-3.

PROCEDURE SHEET

____16.	Study	Lab L-4, Volume-Pressure Relationship, in your lab manual.
____17.	Do	Lab L-4.
____18.	Stop	Have the instructor rate your performance for Lab L-4 before you continue.
____19.	Complete	Checkout Activities for Lab L-4.
____20.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-4.
____21.	Review	Chapters 1 and 2 and Labs L1-4.
____22.	Take	Pneumatics Test #1.
____23.	Stop	Have your instructor evaluate Pneumatics Test #1. If your instructor is satisfied with your performance, continue on to Unit II. Otherwise review the areas suggested by your instructor and repeat Steps 22 and 23.

FORCE TRANSMISSION

UNIT I

TEST

NAME____SCORE__________

1. List three forms of power transmission.

   a.

   b.

   c.

2. Define fluid power.

3. Name four advantages compressed air components may have.

   a.

   b.

   c.

   d.

4. Explain how a force is transmitted through a fluid.

5. Describe how a mechanical force can be multiplied.

TEST

6. State how an intensifier works.

7. Explain the difference between gage pressure and atmospheric pressure.

8. Explain how the two common pressure gages work.

9. Describe how the inclined manometer works.

10. Explain PSIA and PSIG.

TEST

11. What would the absolute pressure be using a vacuum gage, if atmospheric pressure was 24.3 in.--Hg and gage pressure was 6 in --Hg.

12. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

FORCE TRANSMISSION

UNIT I

TEST ANSWERS

1. Mechanical, electrical, and fluid power.

2. Fluid power is power conversion and transmission by gas or liquid means.

3. More compact than other components; operates in any position; reversible with out burnup; can stall under load without burnup.

4. A force applied to a confined fluid is transmitted equally in all directions throughout the fluid in the form of fluid pressure.

5. If an output cylinder piston has more area than an input cylinder piston and a force is applied to the input piston, a force is transmitted in the form of pressure to the large piston and this force will be larger.

6. The input piston is smaller in area than the output piston, hence the output force is intensified.

7. Atmospheric pressure is the pressure the atmosphere exerts on a gage and gage pressure is absolute pressure of a fluid minus the atmospheric pressure.

8. As pressure rises in a system, and a plunger gage, the plunger presses down on the bias spring, which connected to the pointer, moves and consequently the pointer moves. In the bourdon gage, increased pressure causes the curved bourdon tube to straighten out and since the pointer is connected to the tube the pointer moves also.

9. The inclined manometer replaces the U-shaped tube with an inclined one and requires only one reading. This is possible because the incline manometer has a well at one end.

10. PSIA is the actual pressure of fluid plus atmospheric pressure and PSIG is the pressure of a fluid minus the atmospheric pressure.

11. 24.3 in-Hg -- 6 in-Hg = 18.3 in-Hg.

INTRODUCTION TO PNEUMATICS

UNIT II

ENERGY TRANSMISSION - GAS LAW

ENERGY TRANSMISSION - GAS LAW

UNIT II

OBJECTIVES

After completing this unit, the student should be able to work with the ideal gas law and the four other laws, explain how pneumatic energy is transmitted through a compressor, account for inefficiencies in a flow system, show an analogy between fluid and electrical pressure. This knowledge will be shown by end-of-chapter exercises, lab procedures, check-out activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. 1. Explain the Ideal Gas Law (PV=nRT), and how it influences the behavior of a gas.
2. Explain the pneumatic transmission of energy.
3. Discuss how a positive displacement compressor works.
4. State three causes for inefficiency in a pneumatic system.
5. Define the critical velocity of air.
6. Describe how Gas Law #4 may be used.
7. Explain when to use absolute temperatures rather than fahrenheit temperatures.
8. Tell how fluid pressure is like electrical pressure
9. Demonstrate the ability to
    A. Recognize properties of gases and compressed air as related to energy transmission.
    B. Measure fluid gas/compressed air from point of storage to point of use.

ENERGY TRANSMISSION - GAS LAW

UNIT II

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure sheets, test, and lab manual.

   C. Make transparencies.

   D. Discuss unit objectives, specific objectives, and procedure sheets.

   E. Discuss chapter 3 and exercises.

   F. Discuss labs L5-6 and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist students with L5-6 and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

ENERGY TRANSMISSION - GAS LAW

UNIT II

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheets.

   C. Text.

   D. Lab manual.

   E. Test.

   F. Answers to chapter exercises.

   G. Answers to test.

II. References

A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

ENERGY TRANSMISSION - GAS LAW

UNIT II

PROCEDURE SHEET

____1.	Study	Chapter 3, Energy Transmission--Gas Laws, in your text.
____2.	Do	Exercise for Chapter 3 in your text.
____3.	Stop	Have the instructor evaluate the chapter exercise before you continue.
____4.	Study	Lab L-5, Compression & Heat, in your lab manual.
____5.	Do	Lab L-5.
____6.	Stop	Have the instructor rate your performance for Lab L-5 before you continue.
____7.	Complete	Checkout Activities for Lab L-5.
____8.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-5.
____9.	Study	Lab L-6, Measuring Flow & Pressure Drop, in your lab manual.
___10.	Do	Lab L-6.
___11.	Stop	Have the instructor rate your performance for Lab L-6 before you continue.
___12.	Complete	Checkout Activities for Lab L-6.
___13.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-6.
___14.	Review	Chapter 3 and Labs L5 and L6.
___15.	Take	Pneumatic Test #2.
___16.	Stop	Have your instructor evaluate Pneumatic Test #2. If your instructor is satisfied with your performance, continue on to Unit III. Otherwise review the areas suggested by your instructor and repeat Steps 15 and 16.

ENERGY TRANSMISSION - GAS LAW

UNIT II

TEST

NAME____SCORE__________

1. Explain the Ideal Gas Law.

2. Explain pneumatic transmission of energy.

3. Discuss how a positive placement compressor works.

4. State three causes for inefficiency in a pneumatic system.

   a.

   b.

   c.

5. Define the critical velocity of air.

TEST

6. Describe how Gas Law #4 may be used in a fluid system.

7. Explain when to use absolute temperature rather than fahrenheit temperatures.

8. Tell how fluid pressure is like electrical pressure.

9. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

ENERGY TRANSMISSION - GAS LAW

UNIT II

TEST ANSWERS

1. As volume of a system increases, all else constant, the pressure of the system decreases; as temperature of a system increases, all else constant, the pressure of the system increases.

2. Air is stored as potential energy. When the air is released, the potential energy is converted into kinetic energy and heat.

3. As the piston moves down in its cylinder air is drawn in through air intake valves. Then as the piston moves up and the volume is decreased, the intake valve closes and the exhaust valve opens. The air is moved out through the exhaust valve.

4. Heat of compression, friction, and changing fluid direction.

5. It is the maximum velocity at which air can exist in a system.

6. If a gas at P., V., and T. is heated, then either P. and/or V. must increase

$$\left(\frac{P.V.}{T.} = \frac{P_2V_2}{T_2}\right)$$

7. When using gas laws #2, #3, or #4.

8. Electrons flow from generation point to generation point because of voltage. Voltage is electrical pressure and some of the voltage is lost along the way due to resistance. In a fluid system some of the pressure is lost due to flow resistance.

INTRODUCTION TO PNEUMATICS

UNIT III

CONTROL OF PNEUMATIC ENERGY

CONTROL OF PNEUMATIC ENERGY

UNIT III

OBJECTIVE

After completing this unit, the student will be able to explain how pneumatic energy can be controlled through a pressure switch, relief valve, pressure regulator, and directional control valve. This knowledge will be shown through end-of-chapter exercise, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. State why pressure must be controlled at the compressor and after the air receiver tank.
2. Describe how a pressure switch works.
3. Describe how a safety relief valve works.
4. Describe how a pressure regulator works.
5. Describe how a directional control valve works.
6. Describe how a needle valve works.
7. Determine what controls actuator speed.
8. State what an interface is.
9. Tell what differential pressure is.
10. State two safety rules for relief valves.
11. Explain how a pressure regulator is used.
12. Name three uses of directional control valves.
13. Tell where a complete table of pneumatic symbols is located.
14. Demonstrate the ability to
    - A. Troubleshoot an air-to-electric pneumatic control interface.
    - B. Adjust the range and differential of an industrial pressure switch.
    - C. Recognize the safety control in a pneumatic system.

SPECIFIC OBJECTIVES

D. Connect safety relief valves to the compressed air supply.

E. Inspect construction and operating mechanisms of pneumatic pressure regulators.

F. Connect pressure regulator to air supply.

G. Measure directional control in the pneumatic system.

H. Recognize the symbols used for pneumatic fluid power components.

CONTROL OF PNEUMATIC ENERGY

UNIT III

SUGGESTED ACTIVITIES

I. Instructor

- A. Provide students with objective sheet.
- B. Provide students with procedure sheets, test, and lab manual.
- C. Make transparencies.
- D. Discuss unit objectives, specific objectives, and procedure sheets.
- E. Discuss chapter 4 and exercises.
- F. Discuss labs L6-L14 and checkout activities.
- G. Assist students with chapter exercises.
- H. Assist students with labs L6-L14 and checkout activities.
- I. Give test.

II. Student

- A. Read objective sheet.
- B. Complete procedure sheet.
- C. Take test.

CONTROL OF PNEUMATIC ENERGY

UNIT III

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Text.

  D. Lab manual.

  E. Test.

  F. Answers to chapter exercises.

  G. Answers to test.

II. References

  A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

  B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

  C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

  D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

  E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

CONTROL OF PNEUMATIC ENERGY

UNIT III

PROCEDURE SHEET

_____1. Study Chapter 4, Control of Pneumatic Energy, in your text.

_____2. Do Exercise for Chapter 4 in your text.

_____3. Stop Have the instructor evaluate the chapter exercise before you continue.

_____4. Study Lab L-7, Pressure Switch, in your lab manual.

_____5. Do Lab L-7.

_____6. Stop Have the instructor rate your performance for Lab L-7 before you continue.

_____7. Complete Checkout Activities for Lab L-7.

_____8. Stop Have the instructor evaluate the Checkout Activities for Lab L-7.

_____9. Study Lab L-8, Pressure Switch Operation, in your lab manual.

____10. Do Lab L-8.

____11. Stop Have the instructor rate your performance for Lab L-8 before you continue.

____12. Complete Checkout Activities for Lab L-8.

____13. Stop Have the instructor evaluate the Checkout Activities for Lab L-8.

____14. Study Lab L-9, Relief Valve, in your lab manual.

____15. Do Lab L-9.

____16. Stop Have the instructor rate your performance for Lab L-9 before you continue.

____17. Complete Checkout Activities for Lab L-9.

____18. Stop Have the instructor evaluate the Checkout Activities for Lab L-9.

____19. Study Lab L-10, Relief Valve Operation, in your lab manual.

PROCEDURE SHEET

____20.	Do	Lab L-10.
____21.	Stop	Have the instructor rate your performance for Lab L-10 before you continue.
____22.	Complete	Checkout Activities for Lab L-10.
____23.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-10.
____24.	Study	Lab L-11, Pressure Regulator, in your lab manual.
____25.	Do	Lab L-11.
____26.	Stop	Have the instructor rate your performance for Lab L-11 before you continue.
____27.	Complete	Checkout Activities for Lab L-11.
____28.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-11.
____29.	Study	Lab L-12, Pressure Regulator Operation, in your lab manual.
____30.	Do	Lab L-12.
____31.	Stop	Have the instructor rate your performance for Lab L-12 before you continue.
____32.	Complete	Checkout Activities for Lab L-12.
____33.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-12.
____34.	Study	Lab L-13, Directional Control, in your lab manual.
____35.	Do	Lab L-13.
____36.	Stop	Have the instructor rate your performance for Lab L-13 before you continue.
____37.	Complete	Checkout Activities for Lab L-13.
____38.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-13.
____39.	Study	Lab L-14, Symbols, in your lab manual.

PROCEDURE SHEET

____40.	Do	Lab L-14
____41.	Stop	Have the instructor rate your performance for Lab L-14 before you continue.
____42.	Complete	Checkout Activities for Lab L-14.
____43.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-14.
____44.	Review	Chapter 4, Control of Pneumatics Energy, and Labs L6-L14.
____45.	Take	Pneumatics Test #3.
____46.	Stop	Have your instructor evaluate Pnaumatics Test #3. If your instructor is satisfied with your performance, continue on to Unit IV. Otherwise review the areas suggested by your instructor and repeat Steps 45 and 46.

CONTROL OF PNEUMATIC ENERGY

UNIT III

TEST

NAME____SCORE__________

1. State why pressure must be controlled at the compressor and after the air receiver tank.

2. Describe how a pressure switch works.

3. Describe how a safety relief valve works.

4. Describe how a pressure regulator works.

5. Describe how a directional control valve works.

TEST

6. Describe how a needle valve works.

7. Determine what controls actuator speed.

8. State what an interface is.

9. Tell what differential pressure is.

10. State two safety rules for relief valves.

    a.

    b.

TEST

11. Explain how a pressure regulator is used.

12. Name three uses of directional control valves.

    a.

    b.

    c.

13. Tell where a complete table of pneumatic symbols is located.

14. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

CONTROL OF PNEUMATIC ENERGY
UNIT III

TEST ANSWERS

1. At the compressor for safety and after the air receives tank for safety and as an indicator for the actuator to avoid wasting energy.

2. Pressure is served through the inlet to the bottom of the piston. As the pressure increases a linkage to air on/off switch turn on/off a switch.

3. A bias spring holds a poppet closed. As pressure increases to a danger point the poppet compresses the bias spring and opens to relieve pressure. These valves also have manual test levers as they are infrequently operated.

4. This valve is normally open allowing a free flow of air. There is a manual adjustment to adjust flow. When the pressure on this valve reaches the set point the secondary piston moves up relieving the increased pressure.

5. The typical valve consists of a valve body with four internal flow passages and a spool which alternately connects a cylinder part to the supply pressure or to exhaust.

6. The needle valve affects operation by causing a restriction. The speed of an actuator can be controlled with a needle valve only if the load is constant.

7. Actuator speed is determined by how quickly the actuator can be filled and exhausted of air.

8. Air interface is the point at which energy in one media is converted to another for some purpose.

9. It's the difference between a reference pressure and a variable pressure.

10. Install a safety relief valve before any other device at the compressor discharge head. The relief valve must be sized to handle the flow with a certain margin of safety.

11. It is used to admit or deny flow. It can pass flow when it's present and cut down flow when it builds to high and cut off flow when not needed.

12. It can select flow, divert flow, and turn on/off flow.

13. A complete table of ISO symbols is located in Amatrol Technician and Mechanic Library (B353).

INTORDUCTION TO PNEUMATICS

UNIT IV

COMPRESSORS

PNEUMATICS

COMPRESSORS

UNIT IV

OBJECTIVE

After completing this unit, the student should be able to discuss the difference between different types of compressors and explain how a compressor is sized to a load. This knowledge will be shown by completing the end-of-chapter exercise, lab procedures, lab checkout activities, and unit exam with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Explain how a single-stage compressor functions.
2. Explain how a vane compressor functions.
3. Discuss how a helical compressor works.
4. Name four types of helical compressors.
5. Discuss the difference between radial and axial centrifugal compressors.
6. Discuss the difference between a single-stage compressor and a double-stage compressor.
7. List five methods of unloading.
8. Explain the effect altitude bias on a compressor.
9. Tell what three-points compressor sizing depends on.
10. State how to size a compressor.
11. Demonstrate the ability to
    - A. Use the air supply for the air compressor.
    - B. Operate the air compressor.

PNEUMATICS

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with procedure sheets, test, and lab manual.

  C. Make transparencies.

  D. Discuss unit objectives, specific objectives, and procedure sheets.

  E. Discuss chapter 5 and exercises.

  F. Discuss labs L15-L16 and checkout activities.

  G. Assist students with chapter exercises.

  H. Assist students with labs L15-L16 and checkout activities.

  I. Give test.

II. Student.

  A. Read objective sheet.

  B. Complete procedure sheet.

  C. Take test.

PNEUMATICS

UNIT IV

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Text.

  D. Lab manual.

  E. Test.

  F. Answers to chapter exercises.

  G. Answers to test.

II. References

  A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

  B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

  C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

  D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

  E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

PNEUMATICS

UNIT IV

PROCEDURE SHEET

_____1. Study Chapter 5, Compressors, in your text.

_____2. Watch Videotape Supplement for Chapter 5.

_____3. Do Exercise for Chapter 5 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue

_____5. Study Lab L-15, Air Compressor, in your lab manual.

_____6. Do Lab L-15.

_____7. Stop Have the instructor rate your performance for Lab L-15 before you continue.

_____8. Complete Checkout Activities for Lab L-15.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab L-15.

____10. Study Lab L-16, Air Compressor Operation, in your lab manual.

____11. Do Lab L-16.

____12. Stop Have the instructor rate your performance for Lab L-16 before you continue.

____13. Complete Checkout Activiites for Lab L-16.

____14. Stop Have the instructor evaluate the Checkout Activities for Lab L-16.

____15. Review Chapter 5, Compressors, and Labs L-15 and L-16.

____16. Take Pneumatics Test #4.

____17. Stop Have your instructor evaluate Pneumatics Test #4. If your instructor is satisfied with your performance, continue on to Unit V. Otherwise review the areas suggested by your instructor and repeat Steps 16 and 17.

PNEUMATICS

COMPRESSORS

UNIT IV

TEST

NAME____SCORE__________

1. Explain how a single-stage compressor functions.

2. Explain how a vane compressor functions.

3. Discuss how a helical compressor works.

4. Name four types of helical compressors.

    a.

    b.

    c.

    d.

TEST

5. Discuss the difference between radial and axial centrifugal compressors.

6. Discuss the difference between single and double stage compressors.

7. List five methods of unloading.

   a.

   b.

   c.

   d.

   e.

8. Explain the affect altitude has on a compressor.

TEST

9. Tell three points that compressor sizing depends on.

   a.

   b.

   c.

10. State how to size a compressor.

11. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about requirements and possible retesting.

PNEUMATICS

COMPRESSORS

UNIT IV

TEST ANSWERS

1. The compressor is made of a single cylinder and piston with an inlet valve and outlet valve. With the inlet open air is drained into the cylinder as the piston moves to increase the volume.. To compress the air, the inlet closes and the outlet opens as the piston moves to decrease the volume.

2. The shaft attached rotor is offset in a housing. Movable vanes attached to the rotor draw in air as they move in a circular motion and swing outward increasing the volume for the first half cycle. On the second half cycle the volume is decreased as the vanes are moved back into the shaft by the housing. The compressed air is then dumped to a receiver tank and the process starts over.

3. The compressor consists of two helical screws which rotate side by side in a housing. Air is compressed as the screw rotates.

4. Dry helical, oil flooded, single screw and lobed-rotor.

5. Radial compressors have flow rotate as it is compressed about an axis. Speeds are in the range of 50,000 to 100,000 RPM and deliver 350 CFM. Axial compressors have air flow along the axis and rotate at speeds up to 125,000 RPM and deliver 135,000 CFM.

6. A double stage has two pistons and cylinders in line and connected by air intercooler liner. Air is partially compressed and passed on through the intercooler into the second stage where it is finally compressed and more efficiently.

7. Bypass, start stop, inlet valve regulation, inlet throttling, inlet closure.

8. The higher the altitude the lower the pressure density therefore the capacity of the compressor drops.

9. --The system demand and short term projections.
   --Standby capacity for emergency situations.
   --Future plans.

10. --Survey pneumatic tools actuator and blow gun or jets.
    --Get the consumption of each.
    --Find average use time plus 30%--50%.
    --Add storage tank to cushion demand loads.

INTRODUCTION TO PNEUMATICS

UNIT V

COMPRESSED AIR: CONDITIONING AND DISTRIBUTION

UNIT V

OBJECTIVE

After completing this unit, the student should be able to explain why an aftercooler is used with compressed air, size a receiver system, and give advantages of different kinds of piping systems. This knowledge will be shown by end-of-chapter exercise, lab procedures, lab checkout activities, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. List four reasons an aftercooler is used on compressed air.
2. Explain how an aftercooler condenses out water vapor.
3. Explain what determines the size of a receiver tank.
4. Calculate the size of a receiver tank.
5. Calculate the recharging time.
6. List the advantages of the three piping systems.
7. Explain the high cost of leaks.
8. Demonstrate the ability to

   Apply methods of distribution to compressed air.

COMPRESSED AIR: CONDITIONING AND DISTRIBUTION

UNIT V

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure sheets, test, and lab manual.

   C. Make transparencies.

   D. Discuss unit objectives, specific objectives, and procedure sheets.

   E. Discuss chapter 6 and exercises.

   F. Discuss labs L17 and checkout activities.

   G. Assist students with chapter exercises.

   H. Assist students with labs L17 and checkout activities.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheet.

   C. Take test.

COMPRESS AIR: CONDITIONING AND DISTRIBUTION

UNIT V

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Text.

  D. Lab manual.

  E. Test.

  F. Answers to chapter exercises.

  G. Answers to test.

II. References

  A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

  B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

  C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

  D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

  E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

COMPRESSED AIR: CONDITIONING AND DISTRIBUTION

UNIT V

PROCEDURE SHEET

_____1. Study — Chapter 6, Compressed Air: Initial Conditioning and Distribution, in your text.

_____2. Watch — Videotape Supplement for Chapter 6.

_____3. Do — Exercise for Chapter 6 in your text.

_____4. Stop — Have the instructor evaluate the chapter exercise before you continue.

_____5. Study — Lab L-17, Conditioning and Distribution, in your lab manual.

_____6. Do — Lab L-17.

_____7. Stop — Have the instructor rate your performance for Lab L-17 before you continue.

_____8. Complete — Checkout Activities for Lab L-17.

_____9. Stop — Have the instructor evaluate the Checkout Activities for Lab L-17.

____10. Review — Chapter 6 in your text and Lab-17.

____11. Take — Pneumatics Test #5.

____12. Stop — Have your instructor evaluate Pneumatics Test #5. If your instructor is satisfied with your performance, continue on to Unit VI. Otherwise review the areas suggested by your instructor and repeat Steps 11 and 12.

COMPRESSED AIR: CONDITIONING AND DISTRIBUTION

UNIT V

TEST

NAME____SCORE____________

1. List four reasons an aftercooler is used on compressed air.

   a.

   b.

   c.

   d.

2. Explain four ways an aftercooler condenses out water vapor.

   a.

   b.

   c.

   d.

3. Explain what determines the size of a receiver tank.

4. Calculate the size of a receiver tank.

TEST

5. Calculate the recharge time.

6. List advantages of the three-piping systems.

7. Explain the high cost of leaks.

8. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

COMPRESSED AIR: CONDITIONING AND DISTRIBUTION

UNIT V

TEST ANSWERS

1. Compressed air contains excess water vapor, some dirt, some oil vapor and heat.

2. In allowing the air to expand, causes the air to become drier. In refrigerating, the temperature becomes colder and the ability to hold gaseous water is reduced. In the absorption process, water is absorbed by chemical or deliquescent drying agents. In adsorption, dessicant chemicals hold water vapor.

3. Compressor output, size of the system, and air demand cycles determine the size of a receiver tank.

4. For U.S. units: (Q=800 CFM P=80 PSI)

$$V = \frac{3xQx14.7}{P.+14.7} = \frac{3x800x14.7}{80+14.7} = 372\ ft^3$$

for variable demand: (Qi = 900, Qo = 1000, t= 2 min, P1 = 110, P2 = 100)

$$V = \frac{t(Qo - Qi)\ x\ Pa}{(P1 - P2)} = \frac{2\ (1000-900)\ x\ 14.7}{110-100} = 294\ ft^3$$

Qo = flow out
Qi = flow in
Pa = atmos-Pressure

V = receiver size
t = time to charge
P1 = initial working press
P2 = final working press

5. Rearranging the sizing equation:

$$t = \frac{V\ (P1 - P2)}{(Qo - Qi)\ x\ Pa}$$

6. Crid system is simple but delivers only one flow path and work stations near the end are subject to insufficient flow.

--The unit system is made up of two or more systems each with its own compressor allowing short supply line resulting in low pressure drops and easier to adapt to changing requirements.

--The loop system allows optimism conductor size for more equal distribution and parallel path to all work points. Receiver can be located at points of heavy momentary demand.

7. A ½" hole can waste 12 million ft^3 per month which could cost $1,200 per month. Since this air is compressed by electricity, the cost would show up on the electric bill.

INTRODUCTION TO PNEUMATICS

UNIT VI

CHECK VALVE, CYLINDERS AND MOTORS

CHECK VALVE, CYLINDERS AND MOTORS

UNIT VI

OBJECTIVE

After completing this unit, the student should be able to explain when a check valve is to be used, size rods, cylinders and stop tubes, and describe different kinds of motors. This knowledge will be shown by completing end-of-chapter exercise, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Explain how a check valve is used.
2. Explain why seals are used.
3. Describe two types of cylinder loads.
4. List six common types of cylinders.
5. Calculate cylinder size.
6. Explain how a stop tube is selected.
7. Size a rod to prevent buckling.
8. List the factors needed to determine if a cylinder is large enough to absorb shock energy.
9. Select a cylinder to cushion a moving load.
10. Calculate the flow rate into an air cylinder.
11. Explain what is meant by size a cylinder practically.
12. State differences in the four types of motors.
13. Name types of seals used for fluid power.
14. Name three types of air cylinder construction.
15. State the formula for determining the annular area.
16. Explain what is meant by bounce.
17. State when, in terms of speed, is maximum horsepower developed in a CRAM.

SPECIFIC OBJECTIVES

18. Demonstrate the ability to

    A. Use different methods of sealing fluid power devices.

    B. Apply different mountings and modifications to cylinders.

    C. Apply Pascal's Law to linear actuators.

    D. Show linear actuator behavior under load.

    E. Construct a continuous rotary actuator.

    F. Tell the behavior of the vane-rotor types of continuous rotary actuator (CRAM).

    G. Use special function check valves for pneumatic systems.

    H. State the effects of a system check valve.

CHECK VALVE, AND CYLINDERS AND MOTORS

UNIT VI

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with procedure sheets, test, and lab manual.

  C. Make transparencies.

  D. Discuss unit objectives, specific objectives, and procedure sheets.

  E. Discuss chapter 7 and exercises.

  F. Discuss labs L18-L25 and checkout activites.

  G. Assist students with chapter exercises.

  H. Assist students with labs L18-L25 and checkout activities.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheet.

  C. Take test.

CHECK VALVE, AND CYLINDERS AND MOTORS

UNIT VI

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Text.
- D. Lab manual.
- E. Test.
- F. Answers to chapter exercises.
- G. Answers to test.

II. References

A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services 1983.

CHECK VALVE, CYLINDERS AND MOTORS

UNIT VI

PROCEDURE SHEET

_____1.	Study	Chapter 7, Check Valves, Cylinders, Motors, in your text.
_____2.	Watch	Videotape Supplements for Chapter 7.
_____3.	Do	Exercise for Chapter 7 in your text.
_____4.	Stop	Have the instructor evaluate the chapter exercise before you continue.
_____5.	Study	Lab L-18, Seals, in your lab manual.
_____6.	Do	Lab L-18.
_____7.	Stop	Have the instructor rate your performance for Lab L-18 before you continue.
_____8.	Complete	Checkout Activities for Lab L-18.
_____9.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-18.
____10.	Study	Lab L-19, Cylinder (Linear Actuator), in your lab manual.
____11.	Do	Lab L-19.
____12.	Stop	Have the instructor rate your performance for Lab L-19 before you continue.
____13.	Complete	Checkout Activities for Lab L-19.
____14.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-19.
____15.	Study	Lab L-20, Force/Area/Pressure Relationships in Cylinders, in your lab manual.
____16.	Do	Lab L-20.
____17.	Stop	Have the instructor rate your performance for Lab L-20 before you continue.
____18.	Complete	Checkout Activities for Lab L-20.
____19.	Stop	Have the instructor evaluate the Checkout Activities for Lab L-20.

PROCEDURE SHEET

____20. Study Lab L-21, Linear Actuator Operation, in your lab manual.

____21. Do Lab L-21.

____22. Stop Have the instructor rate your performance for Lab L-21.

____23. Complete Checkout Activities for Lab L-21.

____24. Stop Have the instructor evaluate the Checkout Activities for Lab L-21.

____25. Study Lab L-22, Air Motor (Rotary Actuator) in your lab manual.

____26. Do Lab L-22.

____27. Stop Have the instructor rate your performance for Lab L-22.

____28. Complete Checkout Activities for Lab L-22.

____29. Stop Have the instructor evaluate the Checkout Activities for Lab L-22.

____30. Study Lab L-23, Rotary Actuator Operation, in your lab manual.

____31. Do Lab L-23.

____32. Stop Have the instructor rate your performance for Lab L-23.

____33. Complete Checkout Activities for Lab L-23.

____34. Stop Have the instructor evaluate the Checkout Activities for Lab L-23.

____35. Study Lab L-24, Check Valve, in your lab manual.

____36. Do Lab L-24.

____37. Stop Have the instructor rate your performance for Lab L-24.

____38. Complete Checkout Activities for Lab L-24.

____39. Stop Have the instructor evaluate the Checkout Activities for Lab L-24.

____40. Study Lab L-25, Using Check Valves, in your lab manual.

____41. Do Lab L-25.

PROCEDURE SHEET

____42. Stop Have the instructor rate your performance for Lab L-25.

____43. Complete Checkout Activities for Lab L-25.

____44. Stop Have your instructor evaluate the Checkout Activities for Lab L-25.

____45. Review Chapter 7 in your text and Labs L-18 - L-25.

____46. Take Pneumatics Test #7.

____47. Stop Have your instructor evaluate Pneumatics Test #7. If your instructor is satisfied with your performance, continue on to Unit VII. Otherwise review the areas suggested by your instructor and repeat Steps 46 and 47.

CHECK VALVE, CYLINDERS AND MOTORS

UNIT VI

TEST

NAME____SCORE_____________

1. Explain how a check valve is used.

2. Explain why seals are used.

3. Describe two types of cylinder loads.

   a.

   b.

4. List six conversion types of cylinders.

   a.

   b.

   c.

   d.

   e.

   f.

5. Calculate the cylinder size for a rod that will push a load of 300 pounds. The shop supply air is at 90 PSI.

TEST

6. Explain how a stop tube is selected.

7. Find the size of a rod to prevent buckling if the cylinder is to develop 900 lbs thrust and has a stroke of 25 in and a stroke factor of 1.

8. List the factors needed to determine if a cylinder is large enough to absorb shock energy.

9. A 5" base, 2" rod cylinder moves a load of 400#. The average rod speed is 30 ft/min. The cylinder stroke is 5 inches. Will the cylinder be able to cushion the load?

TEST

10. Calculate the flow rate of a 5" base cylinder with a 20" stroch that extends in 4 seconds. This cylinder pushes a load of 500 lbs.

11. Explain what is meant by size a cylinder practically.

12. State the differences in the four types of motors.

    a.

    b.

    c.

    d.

13. Name types of seals used for fluid power.

14. Name three kinds of air cylinder construction.

    a.

    b.

    c.

TEST

15. State the formula for determining the annular area.

16. Explain what is meant by bounce.

17. State, in terms of speed, when is maximum horsepower developed in a CRAM.

18. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

CHECK VALVE, CYLINDERS AND MOTORS

UNIT VI

TEST ANSWERS

1. A check valve allows flow in one direction and at a biared pressure. It can be used to direct flow, trapping flow, limiting pressure, and bypassing flow.

2. A seal is used for proper operation of a pneumatic cylinder by having a positive seal across a cylinder piston and at the rod gland.

3. The two ~~b~~types of cylinder loads are compressive (pushing a load) and tension (pulling a load).

4. Six common types of cylinders are: single acting, spring return, rain, doubleacting, single ro~~a~~d, double rod.

5. Using the compression equation with Pv equal zero.

$$Fc = Pc \times Ap$$

which give assuming Pc = 50 PSI

$$Ap = \frac{Fc}{Pc} = \frac{300}{50} = 6 \text{ in}^2$$

Then inserting the above into the formula for $dp = \sqrt{\frac{Ap\times4}{3.14}} = \sqrt{\frac{6\times4}{3.14}} = 2.7$ in.

6. The stop tube depends on the basic length (=stroke x stroke factor). The stro~~c~~ke factor increases as the cylinder becomes less rigid and is selected from a chart. Then enter a thrust vs. basic length chart to select a stop tube length.

7. Base length = 25x1=25 in.
From the length vs. thrust chart it is found that there is no need for a stop tube and the rod size will need to be [illegible] inch.

8. --Total weight to be moved (fixed as variable).
--Maximum piston speed.
--Distance available for deceleration.
--Direction of load (horizontal or vertical).
--Load friction.
--Whether back pressure exits in the cushion cavity before cushioning takes place.

9. Piston and non-stroke rod = 29 lbs.
Wt of the rod = .89x5 = 4.45 lbs.
Total wt = 29+4.45 = 33.45 lbs.

From a WV graph this gives a cushion rating = 2. Then from a cushion rating chart a value of 20 is found which is more than adequate.

TEST ANSWERS

10. Calculate the pressure - Fc = PcxAp

$$Ap = \frac{3.14(5^2)}{4} = 19.6 \text{ in}^2$$

$$Pc = \frac{Fc}{Ap} = \frac{500}{19.6} = 25.5$$

$$V = AxS = 19.6x20 = 392 \text{ in.}^3$$

$$\text{Compression ratio} = \frac{25.5+14.7}{14.7} = 2.7$$

$$CFM = \frac{392x2.7}{4x28.8} = 9.2$$

11. When sizing a cylinder a design factor of 20% to 50% is included to account for inertia effects of loads and picking the next sized cylinder.

12. Piston motor output ranges from 0.1- 0.2 $\frac{Hp}{in^3}$. They are slow speed and cost-to-power is too high. -vane motor output ranges from 1-4 $\frac{Hp}{in^3}$. The motor is made up of extending vanes attached to an offset shaft that has high pressure air centering an increasing volume and then exhausts the air as the volume decreases.

    --Turbine motor has high pressure air passing through a nozzle that creates a high speed. This high speed air impings on a turbine wheel. This motor has high power-to-weight but due to high rotational speeds is limited to high speed operations.

13. Compression, resilient, mechanical hard face, metal-to-metal, labyrinth.

14. Single acting, spring returned and double acting.

15. Annular area = $\frac{(\text{bore diameter})2}{4} - \frac{(\text{rod diameter})^2}{4}$

16. Air compressibility generally causes a bounce when stopping depending on friction, load, and amount of air trapped.

17. Maximum horsepower is developed at about half of the speed of the CRAM.

INTRODUCTION TO PNEUMATICS

UNIT VII

DIRECTIONAL CONTROL VALVES

DIRECTIONAL CONTROL VALVES

UNIT VII

OBJECTIVE

After completing this unit, the student should be able to explain differences between and functions of directional control valves and name characteristics of sealing in different valves. Also, the student should be able to calculate and size a valve for flow. This knowledge will be shown by completing end-of-chapter exercise, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Explain, for a two-way valve, what an on-off function means.
2. Describe three circuit requirements for which a three-way valve may be used.
3. Name a common use for a four-way valve.
4. Name two ways a valve could be held in a normally open or normally closed position.
5. Explain what is meant by a three-position valve.
6. Name sealing characteristics of four shear action valves.
7. Name characteristics of a poppet valve.
8. Tell how a directional control valve may be moved by air.
9. Explain what is meant by "C-sub-V" as it pertains to flow rating.
10. Calculate CV for a pneumatic grinder.
11. State why a quick response time is becoming important for control valves.
12. List three spool type 3-way control valves.
13. Explain why restrictions in pilot air supply can not be tolerated.
14. Demonstrate the ability to
    A. Pick out different designs of 3-way manual and mechanical operated directional control valves (DCV).
    B. Apply 3-way DCV operation in a circuit with actuators.

SPECIFIC OBJECTIVES

C. Locate 4-way DCV designs using manual and pilot operators.

D. Operate linear actuators with 4-way manual valve.

DIRECTIONAL CONTROL VALVES

UNIT VII

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with procedure sheets, test, and lab manual.

  C. Make transparencies.

  D. Discuss unit objectives, specific objectives, and procedure sheets.

  E. Discuss chapter 8 and exercises.

  F. Discuss labs L26-L29 and checkout activities.

  G. Assist students with chapter exercises.

  H. Assist students with labs L26-L29 and checkout activities.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheet.

  C. Take test.

DIRECTIONAL CONTROL VALVES

UNIT VII

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheets.

   C. Text.

   D. Lab manual.

   E. Test.

   F. Answers to chapter exercises.

   G. Answers to test.

II. References

A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983

B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, in. Amatrol, Inc. 1983.

C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

DIRECTIONAL CONTROL VALVES

UNIT VII

PROCEDURE SHEET

_____1. Study Chapter 8, Directional Control Valves, in your text.

_____2. Watch Videotape Supplement for Chapter 8.

_____3. Do Exercise for Chapter 8 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab L-26, 3-way Manual Valves, in your lab manual.

_____6. Do Lab L-26.

_____7. Stop Have the instructor rate your performance for Lab L-26 before you continue.

_____8. Complete Checkout Activities for Lab L-26.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab L-26.

____10. Study Lab L-27, Actuator Control with Valves, in your lab manual.

____11. Do Lab L-27.

____12. Stop Have the instructor rate your performance for Lab L-27 before you continue.

____13. Complete Checkout Activities for Lab L-27.

____14. Stop Have the instructor evaluate the Checkout Activities for Lab L-27.

____15. Study Lab L-28, 4-way Valves, in your lab manual.

____16. Do Lab L-28.

____17. Stop Have the instructor rate your performance for Lab L-28 before you continue.

____18. Complete Checkout Activities for Lab L-28.

____19. Stop Have the instructor evaluate the Checkout Activities for Lab L-28.

____20. Study Lab L-29, Controlling Actuators with 4-ways, in your lab manual.

PROCEDURE SHEET

____21. Do Lab L-29

____22. Stop Have the instructor rate your performance for Lab L-29 before you continue.

____23. Complete Checkout Activities for Lab L-29.

____24. Stop Have the instructor evaluate the Checkout Activities for Lab L-29.

____25. Review Chapter 8 in your text and Labs L-26 - L-29.

____26. Take Pneumatics Test #8.

____27. Stop Have your instructor evaluate Pneumatics Test #8. If your instructor is satisfied with your performance, continue on to Unit VIII. Otherwise review the areas suggested by your instructor and repeat Steps 26 and 27.

DIRECTIONAL CONTROL VALVES

UNIT VII

TEST

NAME____SCORE_________

1. Explain, for a two-way valve, what an on-off function means.

2. Describe three circuit requirements for which a three-way valve may be used.

   a.

   b.

   c.

3. Name a common use of a four-way valve.

4. Name two ways a valve could be held in a normally open or closed position.

   a.

   b.

5. Explain what is meant by a three-position valve.

TEST

6. Name sealing characteristics of four shear action valves.

7. Name characteristics of a poppet valve.

8. Tell how a directional control valve may be moved by air.

9. Explain what is meant by C-sub-V as it pertains to flow rating.

10. Calculate C_v for pneumatic grinds that require 25 CFM at 100 PSI.

TEST

11. State why a quick response time is becoming important for control valves.

12. List three spool type 3-way control valves.

a.

b.

c.

13. Explain why restrictions in pilot air supply can not be tolerated.

14. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about requirements and possible retesting.

DIRECTIONAL CONTROL VALVES

UNIT VII

TEST ANSWERS

1. This valve consists of two parts. When its spool is extended in one direction the two passages are open or on and when the spool is extended in the opposite direction the two passages are closed or off.

2. High cylinder speeds are required. It is required to save on compressed air. Intermediate positions are required.

3. The four-way valve's most common use is to control the motion of double acting cylinders.

4. A valve may be held open/closed with a spring offset or detent.

5. A three-position valve has three positions that the valve may be in: extended left, extended right and center condition.

6. A. Sliding plate - valves wear in as they are used--inaffected materials may be chosen--wear keep parts in contact--the valve tends to keep foreign objects from lodging--not affected by temperature extremes--can be used as flow control and directional control--good air flow in proportion to control valve movement.

   B. Packed spool - maintainable seals--not too susceptible to varnishing--less affected by improper installation--less sensitive to containimation--less costly maintenance--balanced design.

   C. Packed bore--available in variety of flow patterns--balanced spool--resilient seals--limited valve spool contact - lubricated - won't bind--seals are changeable.

   D. Lapped spool--any flow path--spool shifting easy--easy to position spool--can eliminate crossover flow--won't lose its sealability.

7. Poppett valves offer--raped cycling--reliable--short stroke--resilient seals--resistant to foreign matter--readily maintainable--uneffected by materials passing through.

8. Directional control valves can be shifted by air through pilot pressure.

9. C-sub-V is derived from an expression which gives the number of gallons per minute that will pass through a valve with a 1 PSI differential between valve's inlet and outlet.

TEST ANSWERS

10. Using a two-way valve and take a 10 PSI drop across the valve gives:

Upstream pressure = tool pressure + pressure drop
= 100 + 10 = 110 PSI

Ten Cu = CFMxA
= 25x.030
Cu = .75

11. It's becoming more important to control rapidly moving machinery and give split second accuracy of operation.

12. The spool type 3-way DCU is available in packed bore, packed spool or packlers.

13. A plentiful supply of pilot pressure and flow is necessary to assume complete spool shift.

INTRODUCTION TO PNEUMATICS

UNIT VIII

FLOW CONTROL VALVES, EXHAUST, SILENCERS

FLOW CONTROL VALVES, EXHAUST, SILENCERS

UNIT VIII

OBJECTIVE

After completing this unit, the student should be able to select a fixed or adjustable orifice to control speed in a circuit and select the correct silencer for a circuit. This knowledge will be shown by completing end-of-chapter exercise, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. List four things that affect flow through air orifice.
2. Name examples of fixed and adjustable orifices.
3. Describe where sandwich flow controls are placed in a circuit.
4. Discuss how a four ported four-way valve is used to control the speed of a double-acting cylinder.
5. Explain how flow control valves are used to accomplish multiple speed control.
6. Describe how "jump" in flow control is overcome.
7. Explain how a quick exhaust valve functions.
8. List three things a silencer should have.
9. State how needle valves and flow control valves work to control actuator speed.
10. Give reasons for multiple speed control.
11. List six types of sequencing actuators.
12. Name the frequent problem contributing to short silencer life.
13. Explain the maintenance necessary for an air beaming.
14. Demonstrate the ability to
    A. Use the family of two-way valves.
    B. Apply the needle valve to a circuit.

SPECIFIC OBJECTIVES

C. Troubleshoot volume control valves used with double acting actuators.

D. Operate multiple speed pneumatic circuits with two and three-way valve speed control.

E. List some methods of sequencing actuators with simple valves.

F. Maintain pneumatic silencers.

G. Apply compressed air to industrial machinery.

FLOW CONTROL VALVES, EXHAUST, SILENCERS

UNIT VIII

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with procedure sheets, test, and lab manual.

  C. Make transparencies.

  D. Discuss unit objectives, specific objectives, and procedure sheets.

  E. Discuss chapter 9 and exercises.

  F. Discuss labs L30-L36 and checkout activities.

  G. Assist students with chapter exercises.

  H. Assist students with labs L30-L36 and checkout activities.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheet.

  C. Take test.

FLOW CONTROL VALVES, EXHAUST, SILENCERS

UNIT VIII

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheets.

   C. Text.

   D. Lab manual.

   E. Test.

   F. Answers to chapter exercises.

   G. Answers to test.

II. References

   A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

   B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

   C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

   D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

   E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

FLOW CONTROL VALVES, EXHAUST, SILENCERS

UNIT VIII

PROCEDURE SHEET

_____1. Study Chapter 9, Flow Controls, Silencers, in your text.

_____2. Watch Videotape Supplement for Chapter 9.

_____3. Do Exercise for Chapter 9 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab L-30, Two-way Valves, in your lab manual.

_____6. Do Lab L-30.

_____7. Stop Have the instructor rate your performance for Lab L-30 before you continue.

_____8. Complete Checkout Activities for Lab L-30.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab L-30.

____10. Study Lab L-31, Two-way Valves Applied, in your lab manual.

____11. Do Lab L-31.

____12. Stop Have the instructor rate your performance for Lab L-31 before you continue.

____13. Complete Checkout Activities for Lab L-31.

____14. Stop Have the instructor evaluate the Checkout Activities for Lab L-31.

____15. Study Lab L-32, Speed Control, in your lab manual.

____16. Do Lab L-32.

____17. Stop Have the instructor rate your performance for Lab L-32 before you continue.

____18. Complete Checkout Activities for Lab L-32.

____19. Stop Have the instructor evaluate the Checkout Activities for Lab L-32.

____20. Study Lab L-33, Multiple Speed Control, in your lab manual.

PROCEDURE SHEET

____21. Do Lab L-33.

____22. Stop Have the instructor rate your performance for Lab L-33 before you continue.

____23. Complete Checkout Activities for Lab L-33.

____24. Stop Have the instructor evaluate the Checkout Activities for Lab L-33.

____25. Study Lab L-34, Sequencing Actuators, in your lab manual.

____26. Do Lab L-34.

____27. Stop Have the instructor rate your performance for Lab L-34 before you continue.

____28. Complete Checkout Activities for Lab L-34.

____29. Stop Have the instructor evaluate the Checkout Activities for Lab L-34.

____30. Study Lab L-35, The Silencer, in your lab manual.

____31. Do Lab L-35.

____32. Stop Have the instructor rate your performance for Lab L-35 before you continue.

____33. Complete Checkout Activities for Lab L-35

____34. Stop Have the instructor evaluate the Checkout Activities for Lab L-35.

____35. Study Lab L-36, The Air Bearing, in your lab manual.

____36. Do Lab L-36.

____37. Stop Have the instructor rate your performance for Lab L-36 before you continue.

____38. Complete Checkout Activities for Lab L-36.

____39. Stop Have the instructor evaluate the Checkout Activities for Lab L-36.

____40. Review Chapter 9 in your text and Labs L30 - L36.

____41. Take Pneumatics Test #9.

____42. Stop Have your instructor evaluate Pneumatics Test #9. If your instructor is satisfied with your performance, continue on to Unit IX. Otherwise review the areas suggested by your instructor and repeat Steps 41 and 42.

PNEUMATICS

FLOW CONTROL VALVES, EXHAUST, SILENCERS

UNIT VIII

TEST

NAME____SCORE____________

1. List four things that affect flow through an orifice.

    a.

    b.

    c.

    d.

2. Name examples of fixed and adjustable orifices.

3. Describe where sandwich flow controls are placed in a circuit.

4. Discuss how a four ported four-way valve is used to control the speed of a double acting cylinder.

TEST

5. Explain how flow control valves are used to accomplish multiple speed control.

6. Describe how "jump" in flow control is overcome.

7. Explain how a quick exhaust valve functions.

8. List three qualities a good silencer should have.

   a.

   b.

   c.

9. State how needle valves and flow control valves work to control actuator speed.

TEST

10. Give reasons for multiple speed control.

11. List six types of sequencing actuators.

    a.

    b.

    c.

    d.

    e.

    f.

12. Name the frequent problem contributing to short silencer life.

13. Explain the maintenance necessary for an air bearing.

14. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

PNEUMATICS

FLOW CONTROL VALVES, EXHAUST, SILENCERS

UNIT VIII

TEST ANSWERS

1. Four things that affect flow through an orifice are the size of the orifice, the length of the restriction, the pressure differential across the orifice and the temperature of the fluid.

2. Examples of fixed orifices are pipe plug or check valve with a hole drilled through their center and a factory set control valve. Examples of adjustable orifices are ball valve, globe valve, and needle valve.

3. The sandwich control is best placed close to the cylinder between a valve and its sub-plate.

4. Speed is controlled by how fast the air is allowed to exhaust through the flow control.

5. Extension and retraction speed control can be accomplished with control valves and intermediate speed control may be obtained through the use of a normally-open two-way cam operated valve.

6. Jump is overcome by using quick exhaust valve to eliminate the acceleration of the piston before back pressure is built up. The quick exhaust opens to the higher of two pressures.

7. One example, has a quick exhaust as part of the air supply during extension. But during the return stroke the quick exhaust shifts due to change in pressure allowing the higher pressure to be exhausted to the atmosphere.

8. A good silencer should have low resistance to flow, provide good alternation and be corrosion resistant.

9. Needle valves and flow controls work to control actuator speed by restricting flow thus produces a pressure drop. Reduced pressure produces reduced actuator speed.

10. Multiple speed is needed in drilling sawing and moving materials at more than one speed.

11. Six types of sequencing actuators are--pressure buildings, position sensing, direct time, flow, heat and vibration sequencing.

12. Over-lubrication is the number one cause of short silence life.

13. Since air is flowing outward, the action is self-cleaning and maintenance of the air bearing is limited to good air preparation.

INTRODUCTION TO PNEUMATICS

UNIT IX

AIR PREPARATION

AIR PREPARATION

UNIT IX

OBJECTIVE

After completing this unit, the student should be able to select the proper filter or lubricator. This knowledge will be shown by completing end-of-chapter exercise, lab procedures, lab checkout activities and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Name three contaminant sources possible in a pneumatic system.
2. Name three types of contaminants in a pneumatic system.
3. State the function of an air line filter.
4. Name the two types of filter elements.
5. List industries requiring oil removal filters.
6. Explain how an automatic drain works.
7. Discuss how a filter is selected.
8. Explain how lubrication is accomplished in a pneumatic system.
9. Select a lubricator depending on size of oil particles.
10. Describe how a lubricator is selected.
11. List the rules for designing a system protected by FRLs.
12. Name three submicronic contaminants.
13. Tell the basic difference between a venturi and a pure nozzle.
14. Demonstrate the ability to
    - A. Maintain standard industrial filters.
    - B. Evaluate performance of industrial air line filter elements.

SPECIFIC OBJECTIVES

C. Lubricate compressed air components.

D. Measure the relationship between air flow velocity and pressure.

E. Adjust operation of compressed air lubricator.

AIR PREPARATION

UNIT IX

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with procedure sheets, test, and lab lab manual.

  C. Make transparencies.

  D. Discuss unit objectives, specific objectives, and procedure sheets.

  E. Discuss chapter 11 and exercises.

  F. Discuss labs L37-L41 and checkout activities.

  G. Assist students with chapter exercises.

  H. Assist students with labs L37-L41 and checkout activities.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheet.

  C. Take test.

AIR PREPARATION
UNIT IX
INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheets.

   C. Text.

   D. Lab manual.

   E. Test.

   F. Answers to chapter exercises.

   G. Answers to test.

II. References

A. Perkins, Don, Industrial Pneumatic Technology, Clarksville, Indiana, Amatrol Inc., 1983.

B. Perkins, Don, Pneumatic Basics Industrial Technology Manual, An Introduction to Pneumatic Fluid Power Vol. I, Clarksville, In. Amatrol, Inc. 1983.

C. Stewart, Harry L., Pneumatic and Hydraulic, Indionapolis, Andel & Co., 1980.

D. Sullivan, James A., Fluid Power, Reston, Virginia, Reston Publishing Co., 1982.

E. Whalen, Bruce R., Basic Instrumentation, Austin, Texas, Petroleum Extensics Services, 1983.

AIR PREPARATION

UNIT IX

PROCEDURE SHEET

_____1. Study Chapter 11, Air Preparation, in your text.

_____2. Watch Videotape Supplement for Chapter 11.

_____3. Do Exercise for Chapter 11 in your text.

_____4. Stop Have the instructor evaluate the chapter exercise before you continue.

_____5. Study Lab L-37, Compressed Air Filtration, in your lab manual.

_____6. Do Lab L-37.

_____7. Stop Have the instructor rate your performance for Lab L-37 before you continue.

_____8. Complete Checkout Activities for Lab L-37.

_____9. Stop Have the instructor evaluate the Checkout Activities for Lab L-37.

_____10. Study Lab L-38, C. A. Filter Performance, in your lab manual.

_____11. Do Lab L-38.

_____12. Stop Have the instructor rate your performance for Lab L-38 before you continue.

_____13. Complete Checkout Activities for Lab L-38.

_____14. Stop Have the instructor evaluate the Checkout Activities for Lab L-38.

_____15. Study Lab L-39, Lubrication, in your lab manual.

_____16. Do Lab L-39.

_____17. Stop Have the instructor rate your performance for Lab L-39 before you continue.

_____18. Complete Checkout Activities for Lab L-39.

_____19. Stop Have the instructor evaluate the Checkout Activities for Lab L-39.

PROCEDURE SHEET

____20. Study Lab-40, Velocity-Pressure Measurement, in your lab manual.

____21. Do Lab L-40.

____22. Stop Have the instructor rate your performance for Lab L-40 before you continue.

____23. Complete Checkout Activities for Lab L-40.

____24. Stop Have the instructor evaluate the Checkout Activities for Lab L-40.

____25. Study Lab-41, C.A. Lubricator Performance, in your lab manual.

____26. Do Lab L-41.

____27. Stop Have the instructor rate your performance for Lab L-41 before you continue.

____28. Complete Checkout Activities for Lab L-41.

____29. Stop Have the instructor evaluate the Checkout Activities for Lab L-41.

____30. Review Chapter 11 in your text and Labs L37 - L41.

____31. Take Pneumatics Test #10.

____32. Stop Have your instructor evaluate Pneumatics Test #10. If your instructor is satisfied with your performance, CONGRATULATIONS! You have completed this course. Otherwise review the areas suggested by your instructor and repeat Steps 31 and 32.

AIR PREPARATION

UNIT IX

TEST

NAME____SCORE__________

1. Name three contaminant sources possible in a pneumatic system.

   a.

   b.

   c.

2. Name three types of contaminants in a pneumatic system.

   a.

   b.

   c.

3. State the function of an air line filter.

4. Name the two types of filter elements.

   a.

   b.

5. List industries requiring oil removal filters.

TEST

6. Explain how an automatic drain works.

7. Discuss how a filter is selected.

8. Explain how lubrication is accomplished in a pneumatic system.

9. Select a lubricator depending on size of oil particles.

10. Describe how a lubricator is selected.

TEST

11. List the rules for designing a system protected by FRLs.

12. Name three submicronic contaminants.

    a.

    b.

    c.

13. Explain the basic difference between a venturi and a pure nozzle.

14. Stop. Have your instructor evaluate your performance for this test. If you scored 80 percent or more you have successfully completed this section. If additional study is required, ask your instructor about study requirements and possible retesting.

AIR PREPARATION

UNIT IX

TEST ANSWERS

1. Three possible sources are built-in, generated and ingested.

2. Three types are hard dirt, soft dirt, and untrained liquids.

3. An air line filter is a device that is placed in the air line at the work station to be protected.

4. Two types of filter elements are depth and edge types.

5. Industries requiring oil removal filters are--medical, chemical, pharmacentical, packaging, food processing and paint spraying.

6. Normally pressure above and below a diaphragm keep the drain closed but as the liquid level rises, a float moves upward until a gasket lifts off an orifice allowing pressure to lower a spool downward which discharges the liquid. The reverse process closes the drain.

7. To select a filter first determine the maximum flow requirements (CFM). Then determine the allowable pressure drops (PSI) at the needed flow. Last, refer to the flow curves on filters to find one that offers the flow rate at the predetermined pressure drop.

8. Air line lubricators introduce oil droplets into the air supply either by tuned pulsing or constant misting.

9. To seelct (le) a lubricator, first determine the size of oil particles. If needed oil particles are from 0.01 to 500 micrometer select a standard air line mist lubricator. If oil particles needed are in the range from 0.01 to 2 micrometers then select a recirculating type lubricator.

10. Determine the maximum flow requirements (CFM) and the pressure drop allowed, then refer to lubricator charts and select the one that exhibits the necessary flow rate and pressure drop.

11. a. Make sure the FRLs are designed for maximum flow rate in their part of the circuit.

    b. Place as close as practical.

    c. Place for easy accessibility.

    d. Install shut off valve ahead of the unit for maintenance.

    e. Locate lubricators higher than points being lubricated.

TEST ANSWERS

12. Three submicronic contaminants are viruses, carbon black, and some tobacco smoke.

13. The venturi is a convergent-divergent nozzle. But unlike an ordinary nozzle, the venturi restores most of the original pressure and all the flow after the nozzle.

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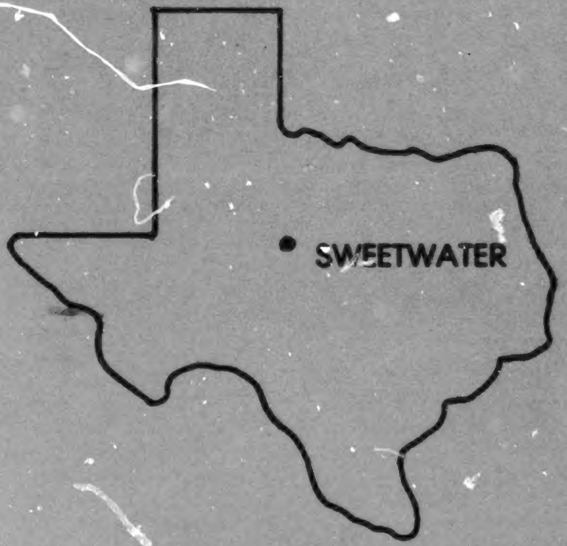

PART II

TEXAS STATE TECHNICAL INSTITUTE
SWEETWATER, TEXAS

1984

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ELECTRIC MOTORS AND CONTROLS

UNIT I

D.C. MOTORS

D. C. MOTORS

UNIT I

UNIT OBJECTIVE

After completing the unit, the student should be able to differentiate among disassemble, clean, and reassemble D.C. motors. The student should also be able to troubleshoot D.C. motors using different test equipment. This knowledge will be shown by completing assignment sheets, lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to:

1. Match terms associated with D.C. motors with their correct definitions.
2. Distinguish between the three types of D.C. motors.
3. Determine a D.C. motor's neutral plane.
4. Demonstrate the ability to disassemble and reassemble a D.C. motor.
5. Demonstrate the ability to locate opens, shorts, and grounds in a D.C. motor using a growler, test light or multimeter.

D. C. MOTORS

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and lab sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information, assignment, and lab sheets.

   F. Demonstrate proper safety procedures.

   G. Summarize the difference between different types of D. C. motors.

   H. Assist students with disassembly and assembly of D. C. motors.

   I. Assist students with learning correct techniques of troubleshooting.

   J. Give test.

II. Student

   A. Read objective sheet.

   B. Study information sheet.

   C. Complete assignment sheets.

   D. Complete lab sheets.

   E. Take test.

D. C. MOTORS

UNIT I

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet.
- B. Information sheet.
- C. Assignment sheets.
- D. Lab sheets.
- E. Test.
- F. Answers to assignment sheets.
- G. Answers to test.

II. References

A. Anderson, Leonard R., Electric Machines and Transformers, Reston, Virginia, Reston Publishing Co., 1981.

B. Hubert, Charles I., Preventive Maintenance of Electrical Equipment, New York, New York, McGraw-Hill, 1979.

C. McIntyre, R. L., Electric Motor Control Fundamentals, New York, New York, McGraw-Hill, 1974.

D. Nadon-Gelmine-McLaughlin, Industrial Electricity, Albany, New York, Delmar Publishers, 1984.

E. Richardson, Donald V., Rotating Electric Machinery & Transformers Technology, Reston, Virginia, Reston Publishing Co., 1982.

F. Rochis - Mazur, Electrical Motor Controls, Alsip, IL, American Technical Publishers, Inc., 1982.

G. Rosenburg, Robert, Electric Motor Repair, New York, New York, Holt, Renehart and Winston, 1970.

UNIT I

INSTRUCTIONAL MATERIALS

H. Sutton, Mack C., Electric Motor Repairman, Austin, Texas, Instructional Material Services, University of Texas, 1973.

III. Additional Material

A. Motor and Motor Controls, New York, New York, The Electrification Council, 1975.

B. Rotating Electrical Machinery, Vincennes, Indiana, Crow Universal Scientific Company Inc., 1954.

D. C. MOTORS

UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Constant speed--the speed can be set at any of several different speeds and will remain practically constant regardless of load changes.

B. Varying speed--this type of motor slows down as the load increases and speeds up as the load decreases.

C. Adjustable varying speed--the speed can be adjusted gradually over a wide range but once set, it stays essentially constant.

D. Stator--the field or stationary frame of the motor.

E. Rotor--the armature which is mounted on the drive shaft and is free to turn.

F. Commutator--cylinder split into two or more segments, each connected to one end of the rotor coil.

G. Brushes--current is supplied to brushes which rub against the commutator.

H. Series-wound motor--the armature and field are connected in series allowing speed to increase as load decreases.

I. Shunt-wound motor--the armature and field are connected in parallel allowing essentially constant motor speed.

J. Compound-wound motor--the shunt field is connected in parallel with the armature and the series field is in series with the armature resulting in high starting torque and essentially constant speed.

K. Starting resistor--a resistor inserted series with the armature to limit starting current to prevent warping the armature on start-up.

L. Mechanical braking--a physical braking system coupled to the motor shaft to produce braking action.

M. Electrical braking--dynamic braking between the motor rotor and stator provided by resistors, plugging or regenerative braking.

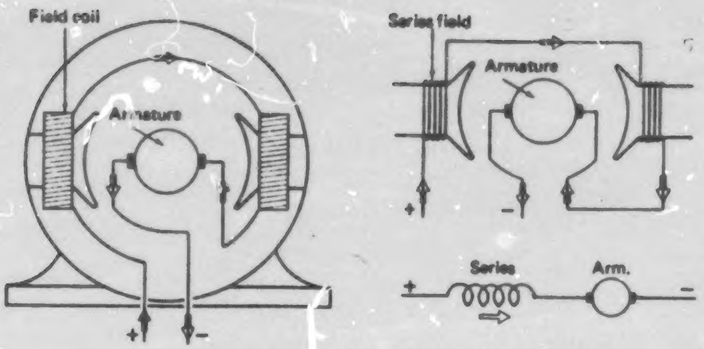
N. Field control--speed control is provided for D.C. series and D.C. shunt motors by increasing the field to decrease the speed.

O. Solid state speed control--a less expensive SCR which replaces the variable resistor to control motor speed.

INFORMATION SHEET

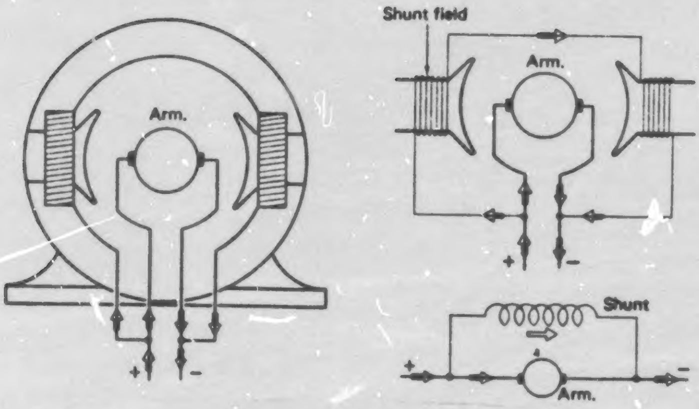
II. Types of D.C. Motors

A.


Field coil
Armature
+
–
Series field
Armature
+
–
Series
Arm.
+
–

Wiring diagram of a typical series D.C. motor.

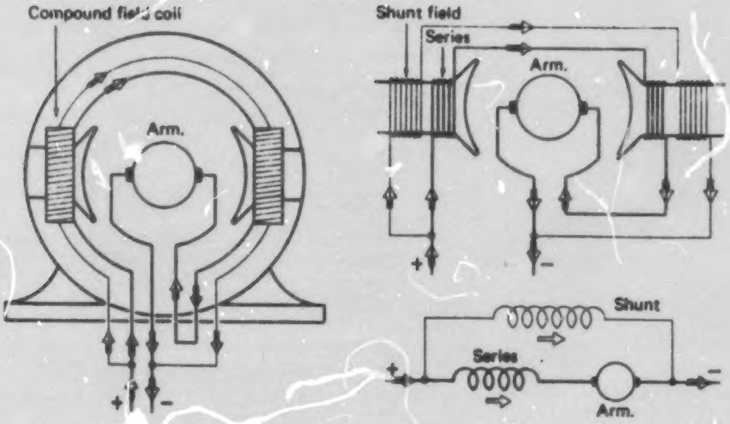
B.


Arm.
+
–
Shunt field
Arm.
+
–
Shunt
+
–
Arm.

Wiring diagram of a typical shunt D.C. motor.

INFORMATION SHEET

C.



Wiring diagram of a typical compound DC motor.

III. Neutral plane for a DC motor.

A. Attach a tachometer to the motor.

B. Measure the speed in both directions with the same load and voltage.

C. If the speed is not the same in both directions, shift the brushes a few degrees and repeat B and C.

D. The correct position is the one that results in the same speed for both directions.

IV. Guidelines for disassembly and reassembly of DC motors.

A. Carefully mark the relationship of the stator end shields, bearing housing and clamping plate and other removable parts with respect to one another.

B. Tag and place small parts in a box.

C. Wrap bearings in clean lintless cloth.

INFORMATION SHEET

D. Motors equipped with bearing housings that slide through the end shield should not have the bearing cap removed unless the bearing is to be changed.

E. Bearings that are locked to both the shaft and the end shield must have the locknut removed before the motor can be disassembled.

F. Bearings that contain oil should be drained before disassembly.

G. All leads to the brush rigging should be disconnected and marked.

H. The brushes should be removed and paper should be taped to the commutator to prevent scratching.

I. If necessary remove bags and file any burrs on the keyway and shaft.

J. To remove the end shield generally, take out the tie bolts and top the lip or knock-off lugs with a mallet.

K. Some bearings are very tightly fitting and require the use of a wheel puller (avoid pry bars).

L. Explosion proof motors require exceptional handling and attention to manufacture instructions (mark parts and do not replace with low strength parts).

V. Locating opens, shorts, and grounds in a DC motor by several methods.

A. Preliminary checks

1. Check overload relay and fuses.

2. Disconnect the control panel and check the control panel for continuity.

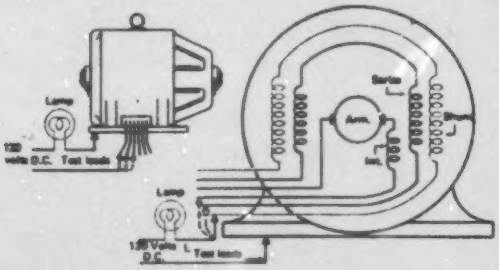
3. Disconnect the controller and check it for continuity.

B. Growler test for shorts

1. Place a growler on the armature and hacksaw blade in the slots, one at a time, and listen for noise which indicates a short in that coil.

C. Lamp tests for grounds (a light indicates a ground).

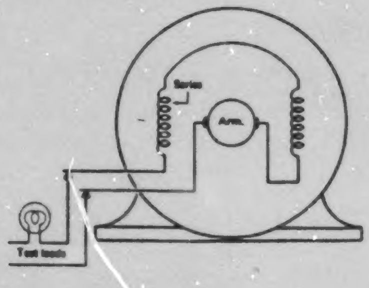
1. Testing a compound motor for grounds.



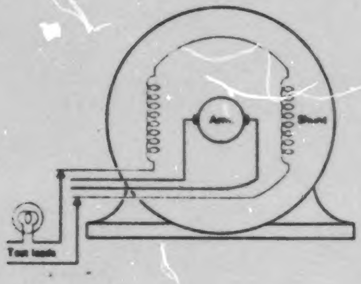
INFORMATION SHEET

D. Lamp tests for opens (no light indicates an open).

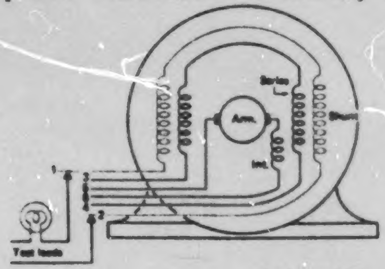
1. The test for an open in a series motor. If the lamp does not light, the trouble may be the brushes, the field, or the connections.

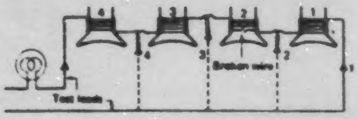

Series
Arm.
Test leads

2. The test of a shunt motor for opens.


Arm.
Shunt
Test leads

3. The test of a compound motor for opens. There are three complete circuits: 1 and 2, 3 and 4, 5 and 6.


Series
Arm.
Shunt
Int.
1
3
2
Test leads


4
3
2
1
4
3
2
1
Broken wire
Test leads

E. Meter test for shorts.

1. Testing for shorted shunt field coils. The voltage drop across each coil should be the same.

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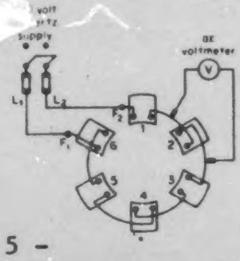
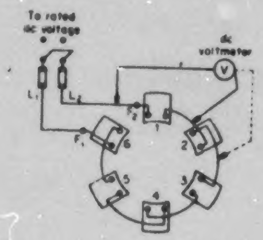

volt
supply
DC voltmeter
V
L1
L2
F2
F1
1
2
3
4
5
6

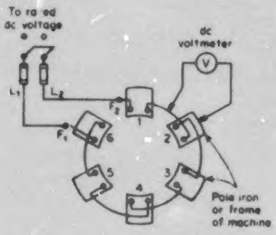
F. Meter test for opens.

1. Locating open shunt field coils. The meter will indicate zero until the coil with the open has been passed.


To rated
dc voltage
dc
voltmeter
V
L1
L2
F2
F1
1
2
3
4
5
6

G. Meter test for ground.

1. Locating grounded shunt field coils. A grounded coil will indicate very low or no voltage when tested from its terminals to ground.


To rated
dc voltage
dc
voltmeter
V
L1
L2
F2
F1
1
2
3
4
5
6
Pole iron
or frame
of machine

D. C. MOTORS

UNIT I

ASSIGNMENT SHEET #1--SKETCH AND LABEL SCHEMATICS FOR THE THREE TYPES OF D.C. MOTORS

A.

B.

ASSIGNMENT SHEET #1

C.

D.C. MOTORS

UNIT I

ASSIGNMENT SHEET #2 - D.C. MOTORS NEUTRAL PLANE

1. If you are trying to locate the correct position for the brushes by sending current through the armature and interpole without any field current, how would you know where to place the brushes.

2. Two neutral points exit on a repulsion-start induction motor. One is the correct neutral (hard) and the other the incorrect one (soft). Explain how you would locate the hard neutral for this type of motor.

D. C. MOTORS

UNIT I

LAB SHEET #1--DISASSEMBLE AND REASSEMBLE D. C. MOTORS

I. Equipment and materials

1. Multimeter
2. Marker
3. Bearing grease
4. Motor oil
5. Heavy paper
6. Mallet or hammer and hardwood blocks
7. Wheel puller
8. Extension pipe
9. Boxes for labeled parts
10. Manufacturer's instructions

II. Procedures - Disassembly

A. Drain oil from bearings if necessary

B. Remove locknut holding shields to shaft; stator end shields, bearing housing, clamping plate and other removable parts.

C. Label all brush riggings.

D. Tie heavy paper around commutator.

E. Place armature on clean cloth.

III. Procedure--Cleaning

A. Clean corroded surfaces.

B. File burrs smooth.

C. Apply light coating of oil or grease to mating parts.

D. Lubricate bearings (use only enough grease).

E. Flush sleeve bearing reservoir with light mineral oil heated to about 75° C. Refill reservoir with recommended oil.

IV. Procedure--Reassembly

A. Reverse disassembly instructions.

LAB SHEET # 1

B. Line up the holes of the end shield with those of the stator and insert side bolts first, tapping gently into place (tighten bolts evenly and alternatively).

C. Drive pulleys with the mallet with the opposite end of shaft backed up with a heavy piece of brass.

D.C. MOTORS

UNIT I

LAB SHEET #2 - LOCATING OPENS, SHORTS, AND GROUNDS IN A D.C. MOTOR

I. Equipment

1. Motors with "problems" set in by your instructor will be provided.
2. Growler
3. Test light
4. Multimeter

II. Procedure

A. Use the procedures outlined in the Information Sheet to locate opens, shorts, and grounds.

B. Show your work to the instructor before proceeding on to the next set-up.

D.C. MOTORS

UNIT I

TEST

NAME______________________________________ SCORE____________

1. Match terms associated with DC motors to their correct definitions. Write the correct numbers in the blanks.

_____a. The speed can be set at any of several different speeds and will remain practically constant regardless of load changes.

_____b. The field or stationary frame of the motor.

_____c. Dynamic braking between the motor rotor and stator provided by resistors, plugging or regenerative braking.

_____d. The shunt field is connected in parallel with the armature and the series field is in series with the armature resulting in high starting torque and essentially constant speed.

_____e. A resistor inserted series with the armature to limit starting current to prevent warping the armature on start-up.

_____f. This type of motor slows down as the load increases and speeds up as the load decreases.

_____g. A less expensive SCR which replaces the variable resistor to control motor speed.

_____h. The speed can be adjusted gradually over a wide range but one set, it stays essentially constant.

_____i. Current is supplied to brushes which rubs against the commutator.

_____j. The armature and field are connected in series allowing speed to increase as load decreases.

_____k. The armature and field are connected in parallel allowing essentially constant motor speed.

1. Compound-wound motor
2. Mechanical braking
3. Varying speed
4. Solid state speed control
5. Series-wound motor
6. Shunt-wound motor
7. Field control
8. Commutator
9. Constant speed
10. Starting resistor
11. Electrical braking
12. Brushes
13. Stator
14. Rotor
15. Adjustable varying speed

TEST

_____l. The armature which is mounted on the drive shaft and is free to turn.

_____m. Cylinder split into two or more segments, each connected to one end of the rotor coil.

_____n. A physical braking system coupled to the motor shaft to produce braking action.

_____o. Speed control is provided for DC series and DC shunt motors by increasing the field to decrease the speed.

2. Label the three different DC motors.

A.____

B.____

TEST

C. ____

3. Arrange in order the following steps used in determining a DC motor's neutral plane by placing the correct required number in the appropriate blank.

_____a. If the speed is not the same in both directions, shift the brushes a few degrees and repeat Band C.

_____b. Attach a tachometer to the motor.

_____c. The correct position is the one that results in the same speed for both directions.

_____d. Measure the speed in both directions with the same load and voltage.

4. Demonstrate the ability to:

a. Disassemble and reassemble a DC motor.

b. Locate opens, shorts and grounds in a DC motor by using a growler, coil light, or multimeter.

5. End oftest. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

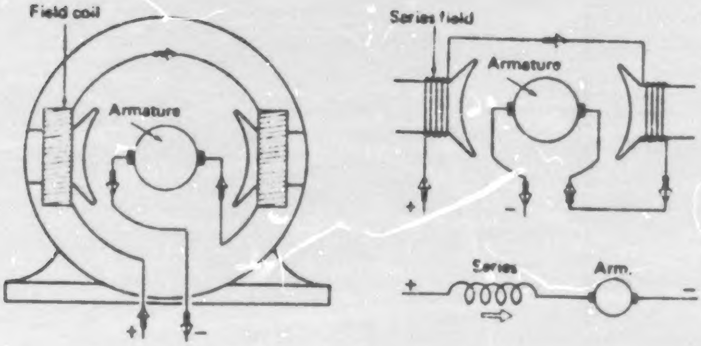
D.C. MOTORS

UNIT I

ASSIGNMENT SHEET #1 - ANSWERS

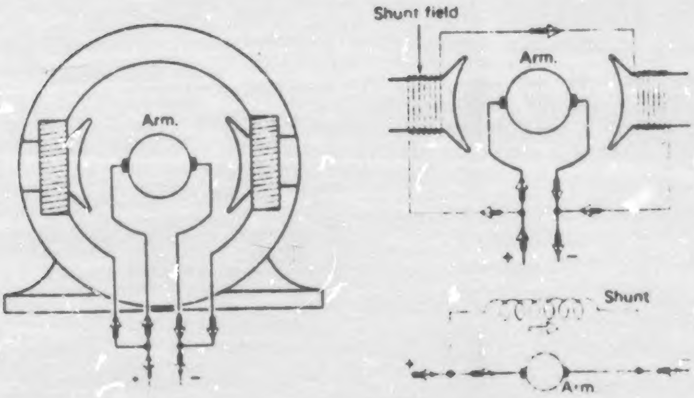
Schematics for three D.C. type motors.

A.


Field coil
Armature
Series field
Armature
+
-
Series
Arm.

Wiring diagram of a typical series D.C. motor.

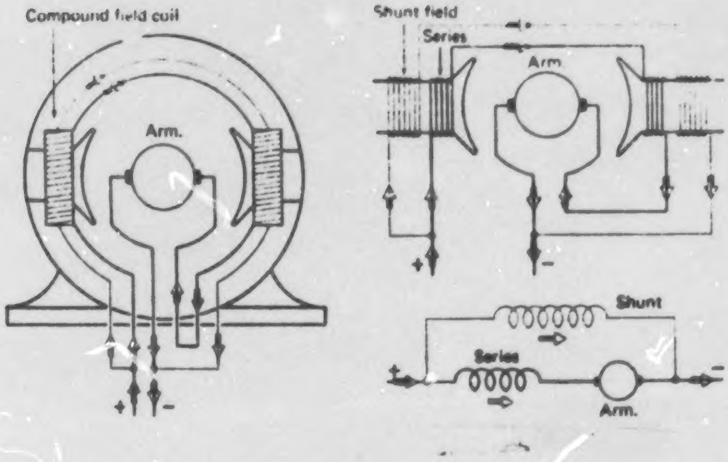
B.


Arm.
Shunt field
Arm.
+
-
Shunt
Arm.

Wiring diagram of a typical shunt D.C. motor.

ASSIGNMENT SHEET #1 - ANSWERS

C.


Compound field coil
Arm.
+
-
Shunt field
Series
Arm.
+
-
Shunt
Series
+
-
Arm.

Wiring diagram of a typical compound DC motor.

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D.C. MOTORS

UNIT I

ASSIGNMENT SHEET #2 - ANSWERS

1. When the brushes are in the neutral position, the armature will not turn.

2. Move the brushes to a point where the motor doesn't run in either direction, then shift the brushes slightly to the right. The motor should run in a clockwise direction. Then shift the brushes to the left. The motor should run in the counter clockwise direction. If the motor runs in the direction in which the brushes have been moved, the correct neutral has been chosen.

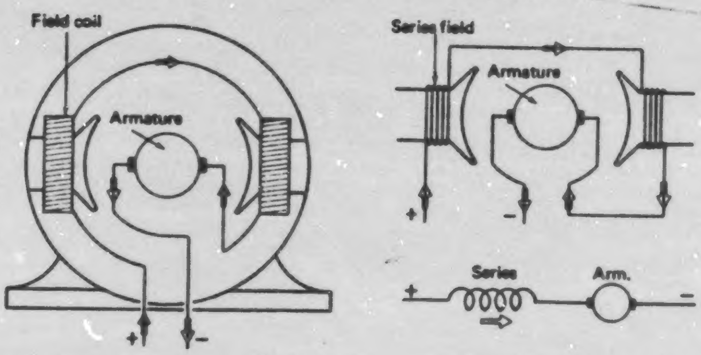
D. C. MOTORS

UNIT I

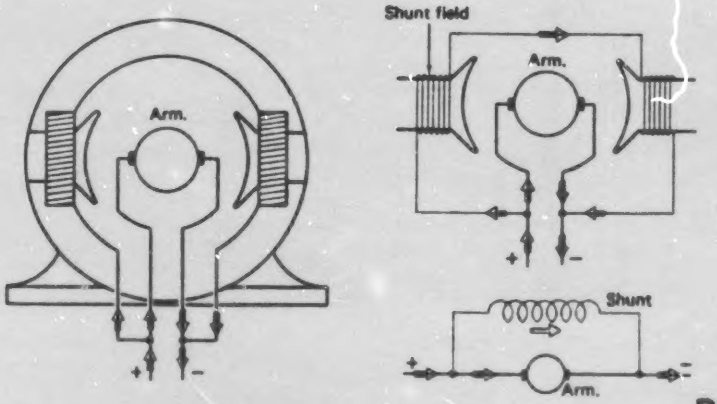
ANSWERS TO TEST

1.
- a. 9
- b. 13
- c. 11
- d. 1
- e. 10
- f. 3
- g. 4
- h. 15
- i. 12
- j. 5
- k 6
- l. 14
- m. 8
- n. 2
- o. 7

2. a. Wiring diagram of a typical series D.C. motor.


Field coil
Armature
+
-
Series field
Armature
+
-
Series
Arm.
+
-

b. Wiring diagram of a typical shunt D.C. motor.


Arm.
+
-
Shunt field
Arm.
+
-
Shunt
+
-
Arm.

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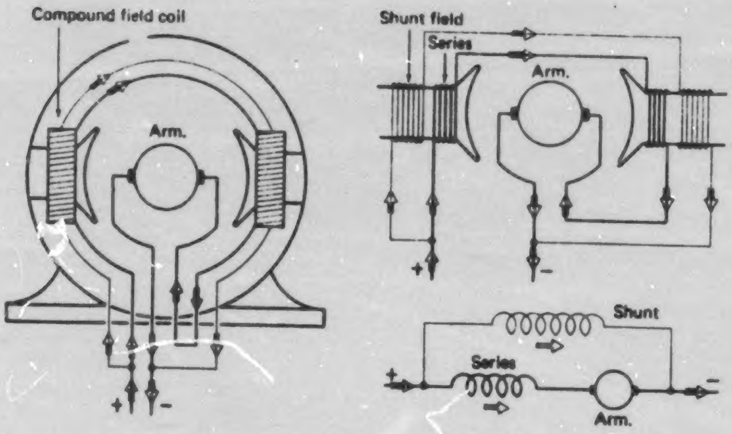
ANSWERS TO TEST

c. Wiring diagram of a typical compound D.C. motor.


Compound field coil
Arm.
+
-
Shunt field
Series
Arm.
+
-
Shunt
Series
Arm.
+
-

3. a. c

   b. a

   c. d

   d. b

ELECTRIC MOTORS AND CONTROLS

UNIT II

D.C. CONTROLS

D.C. CONTROLS

UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to complete controller wiring diagram, connect DC controllers to DC motors and troubleshoot DC controllers using a multimeter and schematic. This knowledge will be shown by completing assignment sheets, lab sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with DC controller with their correct definitions.
2. Troubleshoot a DC controller.
3. Complete a panel wiring diagram of a motor controller using a schematic diagram.
4. Complete internal and external connections for a speed controller and a compound motor.
5. Demonstrate the ability to
    a. Connect a reversing switch in the armature circuit of a short connected to a three-point box.
    b. Connect a manual DC four-point starter box to a DC motor from a schematic.
    c. Connect a DC drum controller to a DC compound motor.

D. C. CONTROLS

UNIT II

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide student with objective sheet.

  B. Provide students with information, assignment, and lab sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information, assignment, and lab sheets.

  F. Demonstrate proper troubleshooting techniques for D. C. Controls.

  G. Summarize methods for wiring controls to motor.

  H. Assist students in correcting D. C. controls to D. C. motor.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Study information sheet.

  C. Complete assignment sheets.

  D. Complete lab sheets.

  E. Take test.

D. C. MOTORS

UNIT II

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Information sheet.

  C. Assignment sheets.

  D. Lab sheets.

  E. Test.

  F. Answers to assignment sheets.

  G. Answers to test.

II. References

  A. Anderson, Leonard R., Electric Machines and Transformers, Reston, Virginia, Reston Publishing Co., 1981.

  B. Hubert, Charles I., Preventive Maintenance of Electrical Equipment, New York, New York, McGraw-Hill, 1979.

  C. McIntyre, R. L., Electric Motor Control Fundamentals, New York, New York, McGraw-Hill, 1974.

  D. Nadon-Gelmine-McLaughlin, Industrial Electricity, Albany, New York, Delmar Publishers, 1984.

  E. Richardson, Donald V., Rotating Electric Machinery & Transformers Technology, Reston, Virginia, Reston Publishing Co., 1982.

  F. Rochis - Mazur, Electrical Motor Controls, Alsip, IL, American Technical Publishers, Inc., 1982.

  G. Rosenburg, Robert, Electric Motor Repair, New York, New York, Holt, Renehart and Winston, 1970.

UNIT II

INSTRUCTIONAL MATERIALS

H. Sutton, Mack C., Electric Motor Repairman, Austin, Texas, Instructional Material Services, University of Texas, 1973.

III. Additional Material

A. Motor and Motor Controls, New York, New York, The Electrification Council, 1975.

B. Rotating Electrical Machinery, Vincennes, Indiana, Crow Universal Scientific Company Inc., 1954.

D.C. CONTROLS

UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Full voltage starting--used to start motors of less than ½ h.p. by placing full voltage across the motor terminals.

B. Rated speed--a limiting speed for a DC motor where the voltage generated by the motor opposes the applied voltage.

C. Reduced voltage starters--used to start motors of ½ h.p. or greater to prevent damage to the commutator and armature windings.

D. Starting resistor--resistor placed in series with the motor to limit starting voltage.

E. Dynamic braking--used to slow a DC motor by disconnecting the armature from the line and inserting a resistor across the terminals.

F. Mechanical braking--a physical brake to provide a DC motor with final stopping.

G. Starting box--the box that the starting resistance is mounted in, usually close to the motor.

II. Troubleshoot a DC controller.

A. If the motor does not start when the handle is moved several points, the trouble may be:

1. Open fuse, breaker, or relay.
2. Open resistance unit.
3. Poor contact between the arm and contact points.
4. Wrong connection on starter boxes.
5. Broken wires.
6. Low voltage.
7. Excessive load.
8. Loose or dirty terminal connections.
9. An open holding coil in a three-point box.

INFORMATION SHEET

B. 1. Familiarize yourself with the elementary diagram by locating the contacts that are associated with each operating coil.

2. From the symptoms of motor behavior, determine which positions of the master switch are involved in the fault.

3. Using the elementary diagram as a guide, make a checklist of the operating coils and contacts, including the master-switch contacts, that should be energized for each master-switch position in question, and then sketch the power circuit for each of these positions. The power circuit for each of the master-switch positions for the hoist control in Fig. 13-9 is drawn with heavy lines in Fig. 13-10.

4. Using the checklist as a reference, operate the master switch, and determine whether these contactors or relays are functioning properly. Correct or replace the faulty ones. When testing the control, it is best that the motor be disconnected. This can be done by disconnecting the motor at the control terminals, removing the test links, or by opening a separate motor disconnect switch if one is provided; the hoist system in Fig. 13-5 has separate switches for the motor and the control.

5. If all contactors and relays appear to function normally and the supply voltage is correct, the trouble must be in the resistor bank or in the motor.

C. The motor will not run in any positon of the master switch. However, clacking of contactors occurs when moving the master switch from "off" to 1 "hoist" or "off" to 1 "lower."

Solution: Because all hoist and lower master-switch positions are involved, it is only necessary to check the diagram for those contacts or relays that could block the current to all hoisting and lowering coils. The common path of current to the operating coils for hoisting and lowering is from L_1, through the fuse, safety switch SW, "reset" contact, and LV_a contact. Because come clacking of contacts occurs, the fuse must be good. Hence, the fault must be with any one or combination of the following:

a. The SW or "reset" contacts in the master switch may be corroded, badly pitted, have defective springs, or loose connections.

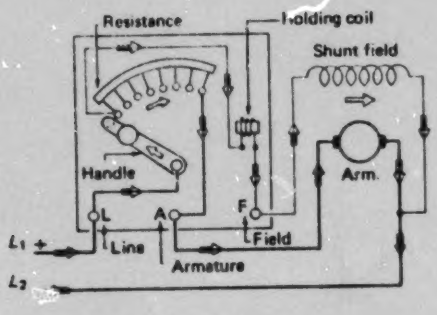
b. Operating coil LV may be open, have a loose connection, or the OL contact in series with it may be corroded, have a weak spring, or a loose connection.

c. Contact LV_a may be defective.

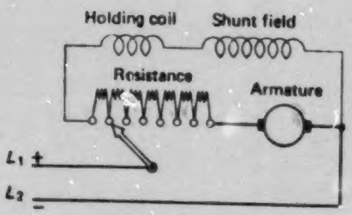
INFORMATION SHEET

III. Complete a panel wiring diagram of a motor controller using a schematic diagram.

A simplified wiring diagram of a motor control looks like:


Resistance
Holding coil
Shunt field
Handle
Arm.
L
A
F
L1 +
Line
Field
Armature
L2

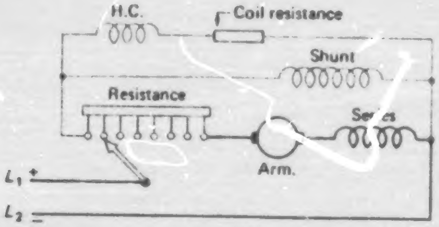
A schematic of the actual wiring would look like:


Holding coil
Shunt field
Resistance
Armature
L1 +
L2 −

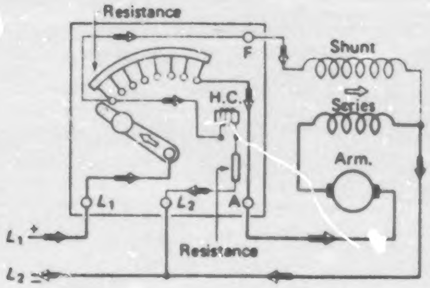
INFORMATION SHEET

IV. Internal and external connections for a speed controller and a compound motor.

A simple wiring diagram for a speed controller looks like:


H.C.
Coil resistance
Shunt
Resistance
Series
Arm.
L_1 +
L_2 −

A schematic of the hard wiring of the above diagram would look like:

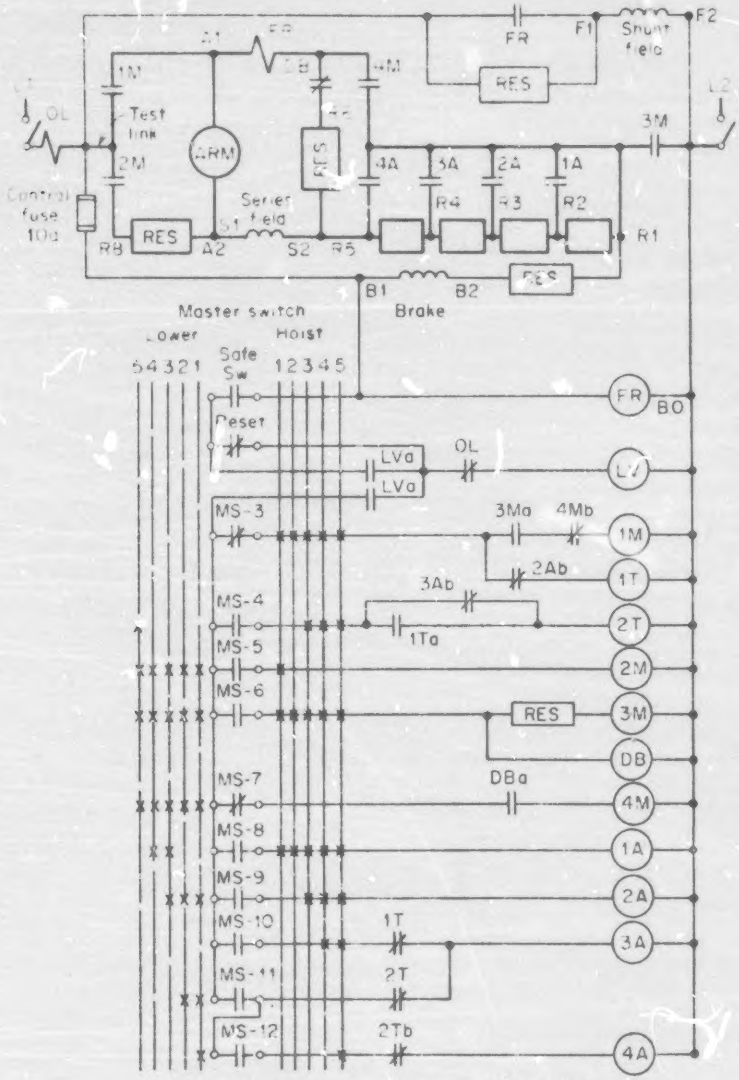

Resistance
F
Shunt
Series
H.C.
Arm.
L_1
L_2
A
Resistance
L_1 +
L_2 −

D.C. CONTROLS

UNIT II

ASSIGNMENT SHEET #1 - TROUBLESHOOTING A D.C. CONTROLLER

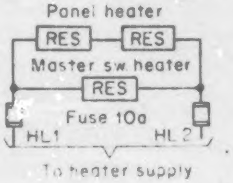
1. The motor lowers but will not hoist in any position of the master switch.


L1
OL
1M
Test link
2M
Control fuse 10a
RB
RES
A1
FR
DB
4M
ARM
A2
S1
Series field
S2
RES
R5
4A
3A
2A
1A
R4
R3
R2
R1
FR
F1
Shunt field
F2
RES
L2
3M
B1
Brake
B2
RES
Master switch
Lower
54321
Safe Sw
Hoist
12345
FR
BO
Reset
LVa
LVa
OL
LV
MS-3
3Ma
4Mb
1M
2Ab
1T
3Ab
MS-4
1Ta
2T
MS-5
2M
MS-6
RES
3M
DB
MS-7
DBa
4M
MS-8
1A
MS-9
2A
MS-10
1T
3A
MS-11
2T
MS-12
2Tb
4A

Sequence table

Con-Tact	Lower					Off	Hoist				
	5	4	3	2	1		1	2	3	4	5
1M							X	X	X	X	X
2M	X	X	X	X	X		X				
3M	X	X	X	X	X		X	X	X	X	X
4M	X	X	X	X	X						
1A		X	X				X	X	X	X	X
2A			X	X	X				X	X	X
3A				X	X					X	X
4A					X						X
DB						X					

X = Contact closed


Panel heater
RES
RES
Master sw. heater
RES
Fuse 10a
HL1
HL2
To heater supply

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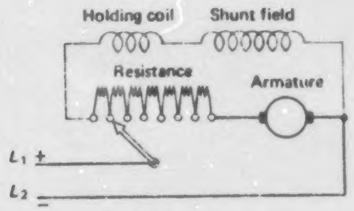
D.C. CONTROLS

UNIT II

ASSIGNMENT SHEET #2--COMPLETE A PANEL WIRING DIAGRAM

A three-point starting box consists essentially of a tapped resistance element that limits the starting current of a motor to a safe value. This type of starter can be used for starting either a shunt or a compound motor. The terminals are L(line), A(armature), and F(field).

Complete a panel wiring diagram of a motor controller using the schematic diagram shown below as a guide.


Holding coil
Shunt field
Resistance
Armature
L_1 +
L_2 −

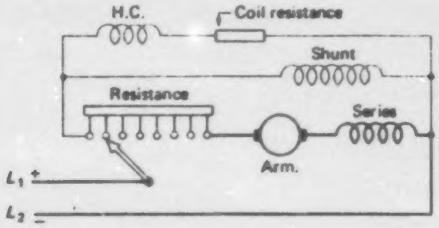
D.C. CONTROLS

UNIT II

ASSIGNMENT SHEET #3--COMPLETE INTERNAL AND EXTERNAL CONNECTION FOR A SPEED CONTROLLER

There is very little difference between the three-point and four-point starting boxes. The main difference is that the holding coil is connected across the line in series with a resistor in order to limit the current in the holding coil. Also the terminals are L and L_2 (line) A (armature) and F (field).

Complete all of the internal and external connections for the speed controller and compound motor as shown in the schematic below.



D.C. CONTROLS

UNIT II

LAB SHEET #1--CONNECTING A REVERSING SWITCH IN THE ARMATURE CIRCUIT TO A THREE-POINT BOX

I. Equipment and materials

  A. Reversing switch

  B. Three-point box

  C. Shunt DC motor

  D. DC power source

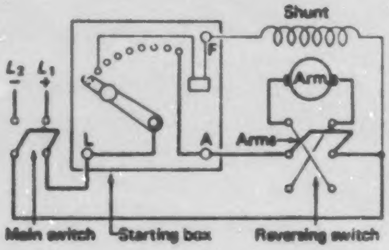
  E. Leads

II. Procedure

  A. Turn off DC power supply

  B. Connect the circuit (figure 1)

FIGURE 1



(NOTE: Have the instructor check your circuit before continuing.)

  C. Turn on the power and bring the handle to the last contact.

  D. Did the motor start and reach its rated speed?________________

  E. Now slowly decrease the voltage to 0 VDC and turn off the power supply.

(NOTE: Discuss your answer with your instructor.)

  F. Did the motor speed decrease to zero?____________________

  G. Throw the reversing switch in the opposite direction and repeat steps C through F.

  H. Did the motor rotate in the opposite direction?________________

(NOTE: Discuss your answer with your instructor.)

LAB SHEET #1

I. Turn off equipment.

J. Put equipment and materials away.

D.C. CONTROLS

UNIT II

LAB SHEET #2--CONNECT A DC FOUR-POINT STARTER BOX TO A DC MOTOR USING A SCHEMATIC

I. Equipment and material

A. Four-point box

B. DC motor

C. DC power source

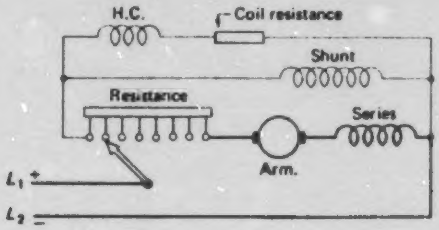
D. Leads

II. Procedure

A. Be sure the DC power source i~~f~~s off.

B. Connect the circuit (figure 1).

FIGURE 1



(NOTE: Have the instructor check your circuit before continuing.)

C. Turn on the power.

D. Slowly bring the starter handle to the first contact point.

E. Did the motor start and attain a slow speed?________________

F. Increase the speed until the starter handle is on the last contact point. Then return the handle to the off position. Turn off the power.

G. Do you observe that the speed of the motor is almost to fast?______________________________

H. Now add a variable resistor to the field circuit.

LAB SHEET #2

I. Again turn on the power.

J. Then turn the handle through the contact points.

K. Do you see that with the field resistor you again have positive speed control?______________________________

(NOTE: Discuss your answer with your instructor.)

L. Turn off equipment.

M. Put equipment and materials away.

D.C. CONTROLS

UNIT II

LAB SHEET # 3--CONNECT A DC DRUM CONTROLLER TO A COMPOUND MOTOR

I. Equipment and materials

A. Drum controller

B. Compound DC motor

C. DC power source

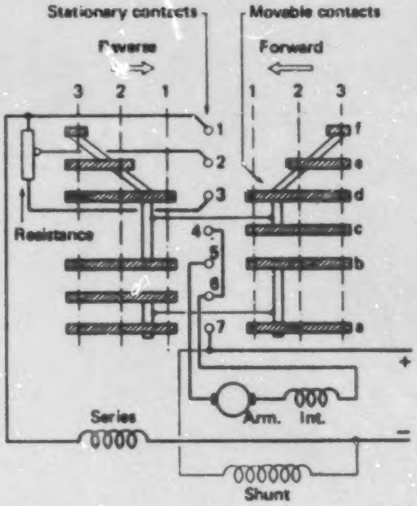
D. LEADS

II. Procedure

A. Be sure power source is off.

B. Connect the circuit (figure 1).

FIGURE 1


Stationary contacts
Movable contacts
Reverse
Forward
3
2
1
1
2
3
1
2
3
4
5
6
7
f
e
d
c
b
a
Resistance
+
Arm.
Int.
Series
−
Shunt

(NOTE: Have the instructor check your circuit before continuing.)

C. Turn on the power.

D. Move the controller handle slowly fully clockwise then back to the beginning position.

E. Which direction did the motor rotate?_________ _______________

F. Now move the controller handle slowly fully in the counterclockwise position then back to the beginning position.

LAB SHEET # 3

G. Did the motor rotate in the opposite direction?__________________

(NOTE: Discuss your answers with your instructor.)

H. Turn off equipment.

I. Put equipment and materials away.

D.C. CONTROLS

UNIT II

TEST

NAME______________________________SCORE__________

1. Match terms associated with DC controllers with their correct definitions. Write the correct number in the blanks.

_____a. Used to start motors of less than ½ h.p. by placing full voltage across the motor terminals.

_____b. A physical brake to provide a DC motor with final stopping.

_____c. Resistor placed in series with the motor to limit starting voltage.

_____d. A limiting speed for a DC motor where the voltage generated by the motor opposes the applied voltage.

_____e. The box the starting resistance is mounted in, usually close to the motor.

_____f. Used to slow a DC motor by disconnecting the armature from the line and inserting a resistor across the terminals.

_____g. Used to start motors of ½ h.p. or greater to prevent damage to the commutator and armature windings.

1. Starting box
2. Reduced voltage starters
3. Rated speed
4. Full voltage starting
5. Mechanical braking
6. Starting resistor
7. Dynamic braking

2. Troubleshooting DC controllers

a. Name at least four reasons why a motor won't start when the handle is moved.

____

____

____

____

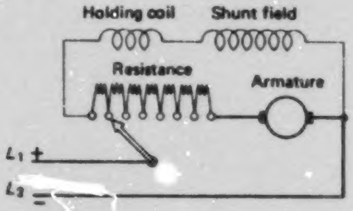
TEST

b. Name at least four reasons a handle won't hold when it is brought to the last point.

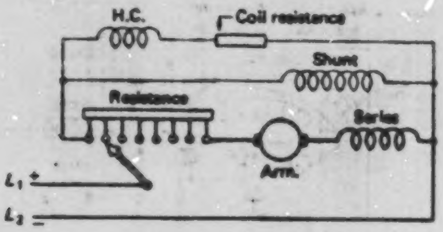
c. Name at least three reasons a fuse blows when a handle is moved up.

d. What are at least two reasons a starting box overheats.

3. Complete a panel wiring diagram of a motor controller using the schematic diagram below as a guide.


Holding coil
Shunt field
Resistance
Armature
L1 +
L2 −

4. Complete internal and external connections for the controller and compound motor shown in the schematic below.


H.C.
Coil resistance
Shunt
Resistance
Series
Arm.
L1 +
L2 −

TEST

5. Demonstrate the ability to

   a. Connect an across-the-line controller to a three-point starter box.

   b. Connect a reversing switch in the armature circuit to a three-point box.

   c. Connect a four-point starter box to a DC motor using a schematic.

   d. Connect a drum controller to a compound motor.

6. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

D.C. CONTROLS

UNIT II

ASSIGNMENT SHEET #1 - ANSWERS

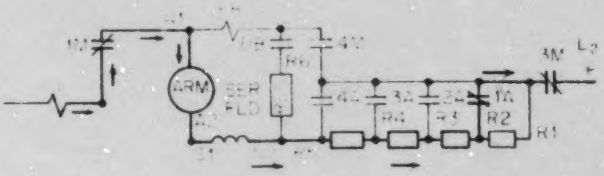
1. The MS contacts common to all hoisting positions are MS_3, MS_6, and MS_8. These contacts serve to energize coils 1M, 3M, DB, and 1A. A sketch of the armature circuit that includes these contactors is shown in Fig. 13-11. The contactors that would prevent operation of the motor are 1M and 3M. However, because the motor does operate satisfactorily in the lower direction, contactor 3M must be in satisfactory condition. Hence, the fault must be with any one or combination of the following:

   a. Master switch contact MS_3 may be corroded, badly pitted, have defective springs, or loose connections.

   b. Coil 1M may be open or have a loose connection.

   c. Contacts $3M_a$ or $4M_b$ may be corroded, badly pitted, have defective springs, or loose connections.

   d. Contact 1M in the power circuit may be badly pitted, have a week spring, or may be binding in the open position.



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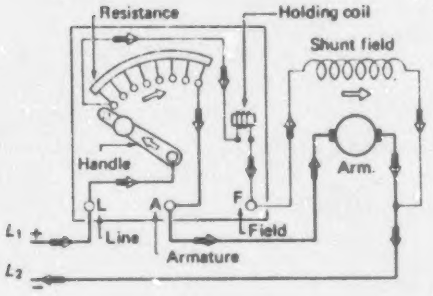
D.C. CONTROLS

UNIT II

ASSIGNMENT SHEET #2 - ANSWERS

1.

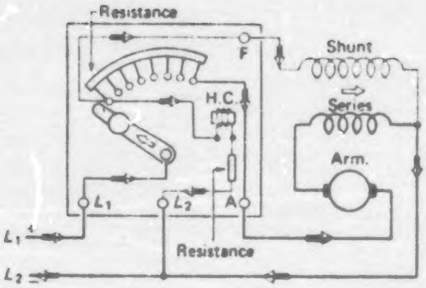

Resistance
Holding coil
Shunt field
Handle
Arm.
L
A
F
L_1 +
Line
Armature
Field
L_2 −

D.C. CONTROLS

UNIT II

ASSIGNMENT SHEET #3 - ANSWERS

1.


Resistance
F
Shunt
H.C.
Series
Arm.
L_1
L_2
A
L_1 +
Resistance
L_2 –

D.C. CONTROLS

UNIT II

ANSWERS TO TEST

1. a. 4 e. 1
   b. 5 f. 7
   c. 6 g. 2
   d. 3

2. a. (1)
      (2)
      (3)
      (4)

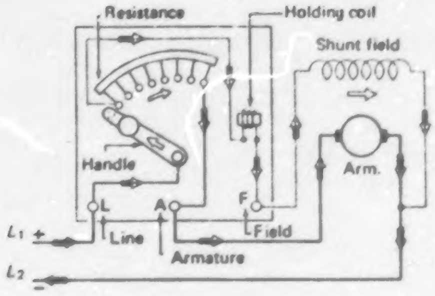
   b. (1)
      (2)
      (3)
      (4)

   c. (1)
      (2)
      (3)

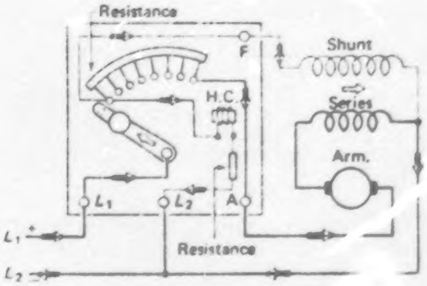
   d. (1)
      (2)

ANSWERS TO TEST

3. (panel wiring diagram of a motor controller)


Resistance
Holding coil
Shunt field
Handle
Arm.
L
A
F
L_1 +
Line
Field
Armature
L_2 −

4. (internal and external connections for controller and compound motor)


Resistance
F
Shunt
H.C.
Series
Arm.
L_1
L_2
A
L_1 +
L_2 −
Resistance

ELECTRIC MOTORS AND CONTROLS

UNIT III

A.C. MOTORS

A.C. MOTORS

UNIT III

OBJECTIVE

After completing this unit, the student should be able to tell the functions and charactersitics of AC motors. The student should also be able to troubleshoot and connect the power to different types of AC motors. This knowledge will be shown by completing assignment sheet, lab sheets, and unit test with a score of 80 percent.

SPECIFIC OBJECTIVES

After completing this course, the student should be able to:

1. Match terms associated with A.C. motors to their correct definitions.
2. Name the characteristic of a capacitor motor.
3. Name the characteristic of a split-phase motor.
4. Name the characteristics of a shaded-pole motor.
5. Name the characteristics of a repulsion-start inductor motor.
6. Name the characteristics of a universal motor.
7. Name the characteristics of a polyphase squirrel cage motor.
8. Name the characteristics of a wound-rotor motor.
9. Demonstrate the ability to:
    - A. Analyze capacitor motor troubles.
    - B. Reverse a shaded-pole motor.
    - C. Wire a dual voltage split-phase motor.
    - D. Connect a three-phase motor in the wye configuration.
    - E. Connect a three-phase motor in the delta configuration.

A. C. MOTORS

UNIT III

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and lab sheets.

   C. Make transparencies

   D. Discuss unit and specific objectives.

   E. Discuss information, assignment, and lab sheets.

   F. Demonstrate proper safety procedures.

   G. Demonstrate procedures for identifying A. C. motors.

   H. Summarize A. C. motor characteristics.

   I. Assist students in troubleshooting and wiring A. C. motors.

   J. Give test.

II. Students

   A. Read objective sheet.

   B. Study information sheets.

   C. Complete assignment sheets.

   D. Complete lab sheets.

   E. Take test.

A. C. MOTORS

UNIT III

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Information sheet.

   C. Assignment sheets.

   D. Lab sheets.

   E. Test.

   F. Answers to assignment sheets.

   G. Answers to test.

II. References

A. Anderson, Leonard R., Electric Machines and Transformers, Reston, Virginia, Reston Publishing Co., 1981.

B. Hubert, Charles I., Preventive Maintenance of Electrical Equipment, New York, New York, McGraw-Hill, 1979.

C. McIntyre, R. L., Electric Motor Control Fundamentals, New York, New York, McGraw-Hill, 1974.

D. Nadon-Gelmine-McLaughlin, Industrial Electricity, Albany, New York, Delmar Publishers, 1984.

E. Richardson, Donald V., Rotating Electric Machinery & Transformers Technology, Reston, Virginia, Reston Publishing Co., 1982.

F. Rochis - Mazur, Electrical Motor Controls, Alsip, IL, American Technical Publishers, Inc., 1982.

G. Rosenburg, Robert, Electric Motor Repair, New York, New York, Holt, Renehart and Winston, 1970.

UNIT III

INSTRUCTIONAL MATERIALS

H. Sutton, Mack C., Electric Motor Repairman, Austin, Texas, Instructional Material Services, University of Texas, 1973.

III. Additional Material

A. Motor and Motor Controls, New York, New York, The Electrification Council, 1975.

B. Rotating Electrical Machinery, Vincennes, Indiana, Crow Universal Scientific Company Inc., 1954.

A.C. MOTORS

UNIT III

INFORMATION SHEET

I. Terms and definitions

A. A.C. motor--essentially a transformer in which the secondary coil is free to move.

B. Stator core--contains the stator windings and fits inside the stator frame.

C. Stator windings--are energized by applied voltage and create a magnetic field inside the motor.

D. Stator frame--supports stator core and mounts on motor base.

E. Rotor shaft--supports the rotor and is supported by bearings in the end shield. It's the power take-off point of the motor.

F. Rotor core--contains the bars (windings) which carry the current induced by the stator magnetic field.

G. Induced current--the induced current in the rotor windings which creates a second magnetic field which opposes the stator magnetic field and causes the motor to turn.

H. End shield--contains the bearings that support the shaft and protects the interior of the motor.

I. Single-phase current--a single alternating current which reverses in a single conductor.

J. Three-phase current--three alternating currents which alternate independently at different times.

K. Single-phase motor--essentially constant speed motors that are more expensive to purchase and maintain, less efficient, and starting currents high.

L. Single-phase induction motor--has one main winding and a starting winding which disconnects after the motor is up to speed.

M. Capacitor motor--has two stator windings, one of which is wired in series with a capacitor and drops out at about 75% speed.

N. Split-phase motor--an induction motor, ½ h.p. or less, used in applications that require low to moderate starting torque, high starting current, constant speed, easy starting, and has two windings one of which drops out at 75% speed.

INFORMATION SHEET

O. Shaded-pole motor--small, low-cost, inefficient, simplest induction motor that uses a shading winding around the main winding to produce a rotative magnetic field for starting torque.

P. Repulsion-start motor--a commutator motor up to 15 h.p. that provides very high starting torque and how starting current in a constant speed induction motor due to the fact that they have centrifugal device that short-circuits the commutator.

Q. Universal motor--a small commu tator motor that operates either on AC/DC, high speeds and provides low horsepower but has a tendency to runaway at no load.

R. Squirrel-cage motor--popular, simple, rugged, easily maintained poly (3) phase motor.

S. Slip--the change in motor speed from sychronous to operating speed expressed as a percentage (5% or greater of synchronous speed is high slip).

T. Starting torque--the amount of torque developed by a motor as it starts (high torque is required for hard starts).

U. Multi-speed squirrel cage--polyphase motor that provides low cost speed adjustment through selecting the number of poles that are operative for 1-4 speeds.

V. Wound rotor motor--a more expensive but more rugged polyphase motor that has 3-phase windings around its rotor, where leads are brought out to slip rings on the motor shaft. Speed is adjusted by varying the external rotor resistance.

II. Characteristics of capacitor motors

A. The motor has at least one capacitor in series with the starting winding.

B. There are squirrel-cage windings in the rotor.

C. The capacitor start motor ranges in size from fractional to 5 h.p. and has high starting torque.

D. The permanent-split capacitor motor has low starting torque but is quiet running and the speed is easily reversed and controlled.

E. The two valve capacitor motor has two sets of windings and capacitor with the auxiliary set used for starting. This motor ranges in size from 5-20 h.p. and features quiet running and limited speed control with high starting torque.

INFORMATION SHEET

III. Characteristics of a split-phase motor

A. This low cost motor is available in fractional sizes (1/20-½ h.p.).

B. It is used widely on small constant speed loads.

C. The motor has low to moderate starting torque due to two sets of windings with the auxiliary set dropping out at around 75% speed.

D. This motor is not good for frequent starting and stopping.

IV. Characteristics of the shaded-pole motor

A. This low cost motor is available in extremely small sizes (1/50-¼ h.p.)

B. Starting torque is developed from shaded windings around a portion of each core in addition to the normal windings.

C. This low-maintenance motor is very inefficient and has a low starting torque.

V. Characteristics of a repulsion-start induction motor.

A. This wound rotor has a commutator and a set of brushes.

B. The motor has high-starting torque and low-starting current.

C. The commutator and brushes are short circuited at a less than normal speed allowing the motor to become an induction motor.

D. This motor is made in sizes up to 15 h.p. and is used to start heavy loads easier than capacitor motors.

VI. Characteristics of the universal motor

A. This motor can be operated either as an AC or DC motor.

B. Typically the small motor has high speed.

C. The motor is built like a series motor therefore the speed increases as the load decreases (it will run away at no load).

D.

VII. Characteristics of polyphase squirrel-cage motors

A. This motor is essentially a constant-speed motor with variations under load.

INFORMATION SHEET

B. Three basic NEMA (B, C and D) designs which decide a motor torque, speed, current, and slip are obtained through rotor slot design.

C. Through rotor design and 60 hertz 3-phase AC current these motors can be adopted to most uses.

D. These motors are simpler, more rugged, more easily maintained and less expensive.

E. Multi-speed squirrel-cage motors have several speeds which are obtained by a selector switch which selects effective poles or separate stator windings.

VIII. Characteristics of a wound-rotor motor

A. This rotor differs from the squirrel cage in that the rotor is equipped with windings instead of bars.

B. Leads from the windings are brought to external variable resistors to provide starting or speed regulation.

C. Torque can also be controlled by varying the external rotor resistance.

D. This motor can accelerate heavy loads gradually and smoothly.

E. Due to the complexity the motor has higher initial cost.

A.C. MOTORS

UNIT III

ASSIGNMENT SHEET #1--CHARACTERISTICS OF SINGLE AND POLY-PHASE MOTORS

1. Name the characteristics of capacitor motors

    a.
    b.
    c.
    d.
    e.

2. Name the characteristics of a split-phase motor

    a.
    b.
    c.
    d.

3. Name the characteristics of shaded-pole motors

    a.
    b.
    c.

4. Name the characteristics of a repulsion-start induction motor

    a.
    b.
    c.
    d.

5. Name the characteristics of the universal motor

    a.
    b.
    c.

ASSIGNMENT SHEET #1

6. Name the characteristics of a poly-phase squirrel-cage motor

   a.

   b.

   c.

   d.

   e.

7. Name the characteristics of a wound-rotor motor

   a.

   b.

   c.

   d.

   e.

A.C. MOTORS

UNIT III

LAB SHEET #1--ANALYZING CAPACITOR MOTOR TROUBLES

I. Equipment and materials

A. Capacitor motor

B. 10 amp fuse

C. Screwdriver, wood handle

D. Lamp

E. Leads

F. Ammeter

G. Voltmeter

H. Power source

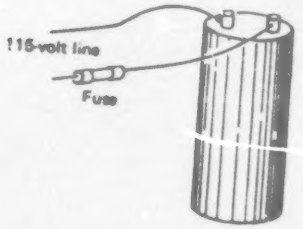
II. Procedure

A. Be sure the power supply is off.

B. Inspect the motor to detect such mechanical troubles as broken or cracked end plates, badly bent shaft, broken or burned leads.

C. To test the capacitors, remove all leads from the capacitor terminals, and connect the capacitor as shown in figure 1.

FIGURE

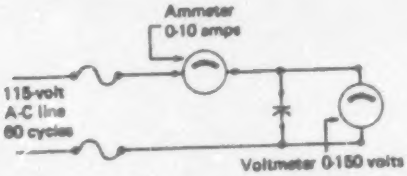


D. If the 10 amps fuse burns out the capacitor is short circuited and must be replaced.

LAB SHEET #1

E. To determine the charge on the capacitor, connect the disconnected capacitor as shown in figure 2.

FIGURE 2


Ammeter
0-10 amps
115-volt
A-C line
60 cycles
Voltmeter 0-150 volts

F. Calculate the capacity using the following formula:

$$\text{Capacity in mf} = \frac{159.300}{\text{frequency}} \times \frac{\text{amperes}}{\text{volts}}$$

(NOTE: Reconnect the leads from the capacitors to motor.)

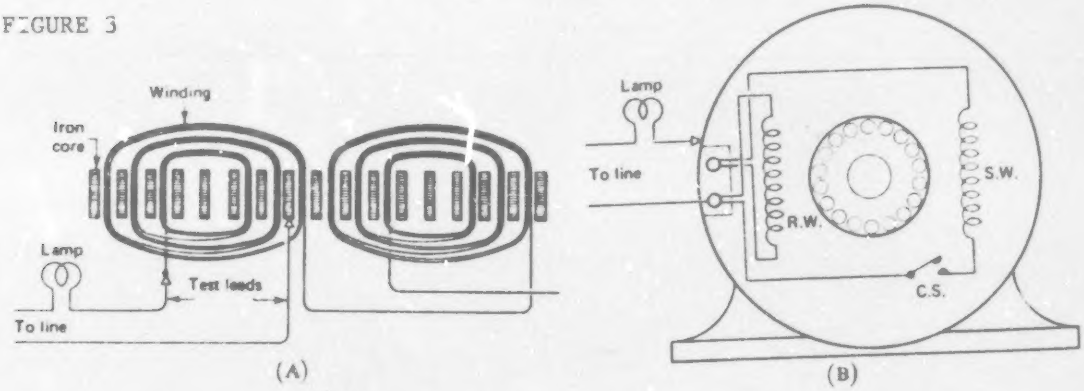
G. Test the motor for bearing trouble by

(1) Trying to remove the shaft up and down.

(2) Turning the shaft by hand to see if it turns freely.

H. Ground test the motor to discover whether internal wires are touching the iron core by connecting the motor as shown in figure 3.

FIGURE 3


Winding
Iron core
Lamp
Test leads
To line
Lamp
To line
S.W.
R.W.
C.S.

(A) (B)

(NOTE: The lighted lamp indicates a ground.)

LAB SHEET #1

I. Next test the motor by connecting it to a power source and turning it on.

(NOTE: If the fuse blows, windings smoke, or motor rotates slowly or not at all continue to step I. If the motor runs with no trouble go to step 0.)

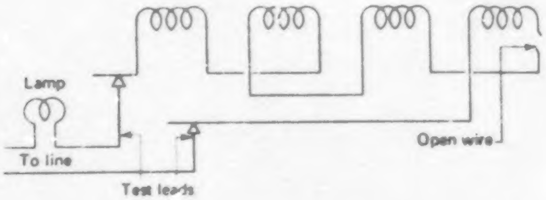
J. Remove the end plates

K. Remove the rotor

L. Test the windings by looking and smelling for burned windings

M. To test for open windings, connect the circuit as shown in figure 4.

FIGURE 4



(NOTE: If the circuit is open, the lamp will not light.)

N. If the windings are open, replace the windings.

O. Reassemble the motor

P. Turn off the equipment

Q. Put up the equipment and materials

A.C. MOTORS

UNIT III

LAB SHEET #2--REVERSING A SHADED-POLE MOTOR

I. Equipment and material

A. Shaded-pole motor

B. Power source, 115/230 VAC

II. Procedure

A. If the motor is externally reversible, go to step H; if not, continue to the next stop.

B. Disassemble the motor

C. Reverse the stator end for end

D. Reassemble

E. Test the motor to verify that it in fact did reverse.

(NOTE: Discuss the results with your instructor.)

F. Turn off the equipment

G. Put up your equipment and materials

H. Check to see if your motor has one main winding with two sets of shaded windings. If it does go to step K.

I. You have the motor that has two sets of main windings and one set of shaded windings.

J. Reverse the main winding wiring to reverse the motor rotation then go to step E.

K. Reverse the shaded pole wiring to reverse the motor rotation then go to step E.

A.C. MOTORS
UNIT III

LAB SHEET #5--WIRING A SPLIT-PHASE DUAL VOLTAGE MOTOR TO 240 VAC

I. Equipment

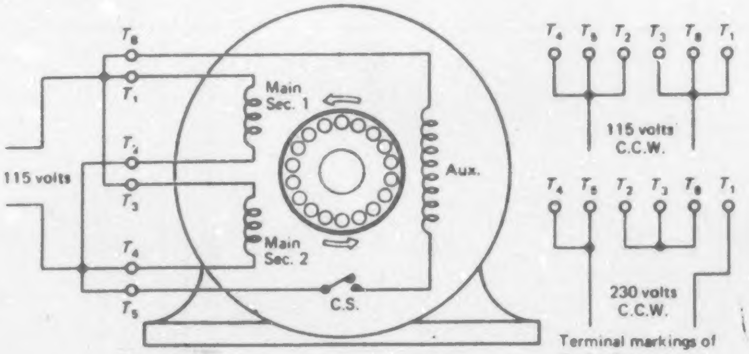
- A. Dual voltage, split-phase motor
- B. Power supply, 115 and 230 VAC

II. Procedure

- A. Disconnect motor from power supply.
- B. Connect terminals T1 - T8 as indicated on figure 1 for 115 VAC.
- C. Connect the motor to 120 VAC.
- D. Turn on the motor and observe whether the motor runs manually then turn off.
- E. Disconnect motor from the power supply.
- F. Connect terminals T1 - T8 as indicated on figure 1 for 230 VAC.
- G. Connect the motor to 240 VAC.
- H. Turn on the motor and observe whether the motor runs normally.
- I. Turn off the equipment.

(NOTE: Discuss your results with your instructor.)

- J. Put up your equipment and materials.


T_8
T_1
T_2
T_3
T_4
T_5
115 volts
Main Sec. 1
Main Sec. 2
Aux.
C.S.
T_4 T_5 T_2 T_3 T_8 T_1
115 volts C.C.W.
T_4 T_5 T_2 T_3 T_8 T_1
230 volts C.C.W.

Terminal markings of dual voltage motor

To reverse - interchange T_5 and T_8

BEST COPY AVAILABLE

A.C. MOTORS

UNIT III

LAB SHEET #4--CONNECTING A THREE-PHASE STAR OR WYE MOTOR

I. Equipment

A. Three-phase motor, 36 coil, four-pole.

B. Power source, 115/230 VAC

II. Procedure

A. Find the number of coils in the three-phase motor.

B. Find the number of coils in each phase by dividing the number of coils by the number of phases. (Example: $\frac{\text{36 coil}}{\text{3 phase}}$ = 12 coils per phase)

C. Then find the number of costs per pole that your motor has by dividing the number of coils by the number of poles. (Example: $\frac{\text{36 coil}}{\text{4 poles}}$ = 9 coils per pole)

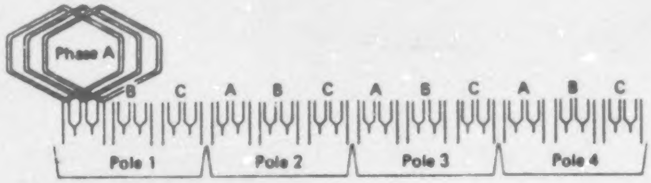
D. Now to find this number in the pole-phase group, divide the number of coils by the number of groups (3-A,B,C) (Example: $\frac{\text{9 coils}}{\text{3 groups}} = \frac{\text{3 coils}}{\text{groups}}$)

E. Now determine the number of groups by multiplying the number of groups times 3 phases. (Example: 4 poles x 3 phase = 12 groups

F. The number of coils per groups is found by dividing the total number of coils by number of groups. (Example: $\frac{\text{36 total coils}}{\text{3 groups}}$ =3 coils per group)

G. Connect the coils in groups as in figure 1.

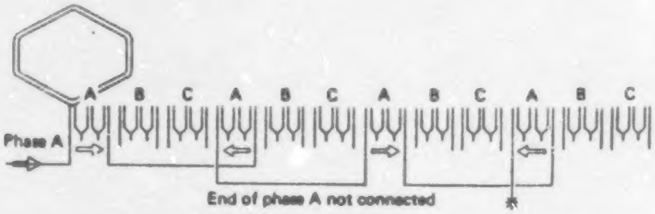
FIGURE 1



LAB SHEET #4

H. Connect groups of A together as shown in figure 2. The groups must be connected so that current flow through one group A in one direction and the next group A in the opposite direction.

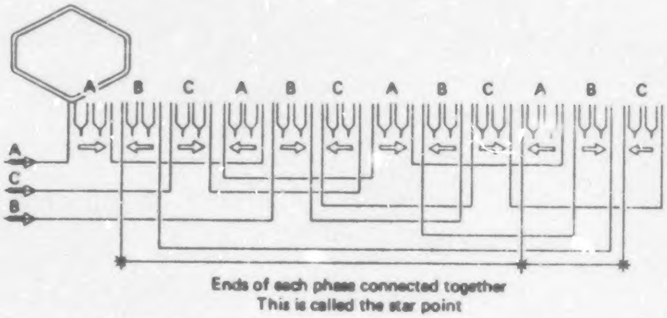
FIGURE 2


A
B
C
A
B
C
A
B
C
A
B
C
Phase A
End of phase A not connected

I. Connect the C phase exactly like the A phase.

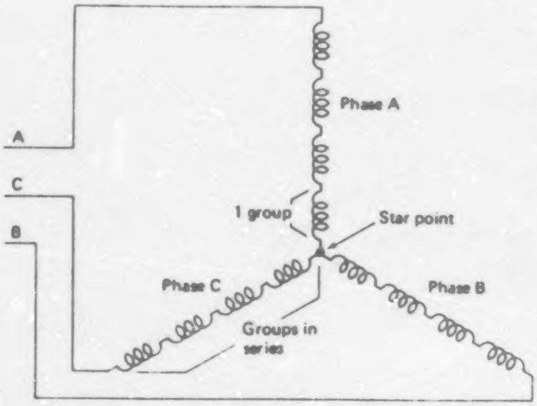
J. Connect the B phase in the same manner as phases A and C using figure 3 as a guide.

FIGURE 3


A
B
C
A
B
C
A
B
C
A
B
C
A
C
B
Ends of each phase connected together
This is called the star point

K. Now complete the wiring by referring to figure 4.

FIGURE 4


A
C
B
Phase A
1 group
Star point
Phase C
Phase B
Groups in series

LAB SHEET #4

(NOTE: Have your instructor check your wiring at this time)

L. Connect the wye motor to a power source.

M. Check your motor by connecting it to a load and rewiring the motor.

N. Turn off the equipment.

(NOTE: Discuss the results with your instructor.)

O. Put up your equipment.

A.C. MOTORS

UNIT III

LAB SHEET #5--CONNECTING A THREE-PHASE DELTA MOTOR

I. Equipment

A. Three-phase motor, 36 coil, four pole.

B. Power source, 115/230 VAC

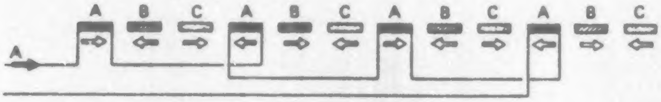
II. Procedure.

A. Use the same steps used on Lab Sheet #4 to find the number of coils per group (Lab Sheet #4, steps A through F).

B. Connect the coils into groups and label each group (A or B or C).

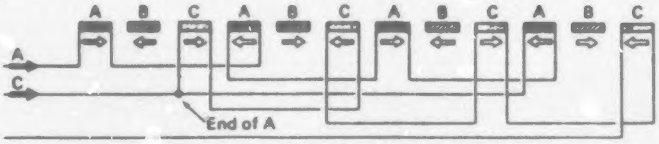
C. Connect phase A groups together as that current will flow one direction in one group and opposite direction in the next group as indicated in figure 1.

FIGURE 1



D. Connect phase groups A and C in the same manner. In this case connect the end of phase A to the start of phase C (see figure 2).

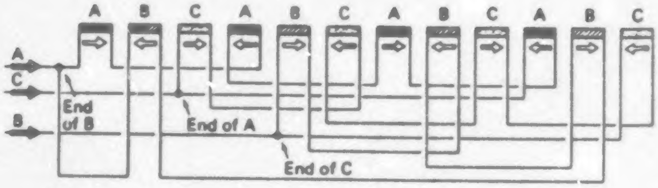
FIGURE 2



LAB SHEET #5

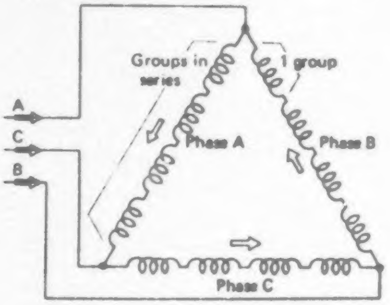
E. Continue by connecting the end of phase C to the beginning of phase B (see figure 3).

FIGURE 3


A
B
C
A
B
C
A
B
C
A
B
C
A
C
B
End of B
End of A
End of C

F. Now complete the wiring by referring to figure 4.

FIGURE 4


Groups in series
1 group
Phase A
Phase B
Phase C
A
C
B

(NOTE: Have your instructor inspect your connection at this time.)

G. Connect the delta motor to a power source.

H. Check your motor by connecting it to a load and running the motor.

I. Turn off your equipment.

(NOTE: Discuss your results with your instructor).

J. Put up your equipment.

A.C. MOTORS

UNIT III

TEST

NAME____ SCORE_______________

1. Match terms associated with A.C. motors to their correct definition. Write the correct numbers in the blanks.

_____a. An induction motor, ½ h.p. or less, used in applications that require low to moderate starting torque, high starting current, constant speed, easy starting, and has two windings one of which drops out at 75% speed.

_____b. A single alternating current which reverses in a single conductor.

_____c. Supports the rotor and is supported by bearings in the end shield. It's the power take-off point of the motor.

_____d. Contains the bearings that support the shaft and protects the interior of the motor.

_____e. A more expensive but more rugged polyphase motor that has 3-phase windings around its rotor, where leads are brought out to slip rings on the motor shaft. Speed is adjusted by varying the external rotor resistance.

_____f. Popular, simple, rugged, easily maintained poly (3) phase motor.

_____g. The amount of torque developed by a motor as it starts (high torque is required for hard starts).

_____h. Essentially constant speed motors that are more expensive to purchase and maintain, less efficient, and starting currents high.

_____i. Are energized by applied voltage and create a magnetic field inside the motor.

_____j. Has two stator windings, one of which is wired in series with a capacitor and drops out at about 75% speed.

1. A.C. motor
2. Split-phase motor
3. Single-phase induction motor
4. Rotor shaft
5. Universal motor
6. Starting torque
7. Wound-rotor motor
8. Multi-speed squirrel cage
9. Single-phase current
10. Stator frame
11. Capacitor motor
12. Squirrel-cage motor
13. Shaded-pole motor
14. Single-phase motor
15. End shield
16. Rotor core
17. Slip

TEST

_____k. Has one main winding and a starting winding which disconnects after the motor is up to speed.

_____l. Three alternating currents which alternate independently at different times.

_____m. Contains the stator windings and fits inside the stator frame.

_____n. Essentially a transformer in which the secondary coil is free to move.

_____o. Supports the stator core and mounts on motor base.

_____p. Contains the bars (windings) which carry the current induced by the stator magnetic field.

_____q. The induced current in the rotor windings which creates a second magnetic field which opposes the stator magnetic field and causes the motor to turn.

_____r. Small, low-cost, inefficient, simplest induction motor that uses a shading winding around the main winding to produce a rotative magnetic field for starting torque.

_____s. A small commutator motor that operates either on AC/DC, high speeds and provides low horsepower but has a tendency to runaway at no load.

_____t. The change in motor speed from synchronous to operating speed expressed as a percentage (5% or greater of synchronous speed is high slip).

_____u. Polyphase motor that provides low cost speed adjustment through selecting the number of poles that are operative for 1-4 speeds.

_____v A cummutator motor up to 15 h.p. that provides very high starting torque and how starting current in a constant speed induction motor due to the fact that they have centrifugal device that short-circuits the commutator.

18. Induced current

19. Stator core

20. Stator windings

21. Repulsion start motor

22. Three-phase current

TEST

2. Name the characteristics of a capacitor motor.

   a.
   b.
   c.
   d.
   e.

3. Name the characteristics of a split-phase motor.

   a.
   b.
   c.
   d.

4. Name the characteristics of shaded-pole motor.

   a.
   b.
   c.

5. Name the characteristics of repulsion start motor.

   a.
   b.
   c.
   d.

6. Name the characteristics of the universal motor.

   a.
   b.
   c.

7. Name the characteristics of squirrel-cage motor.

   a.
   b.
   c.
   d.
   e.

TEST

8. Name characteristics of wound-rotor motor.

   a.

   b.

   c.

   d.

   e.

9. Demonstrate the ability to

   a. Analyze capacitor motor troubles.

   b. Reverse a shaded-pole motor.

   c. Wire a dual voltage split-phase motor.

   d. Connect a three-phase motor in the wye configuration.

   e. Connect a three-phase motor in the delta configuration.

10. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

A.C. MOTORS

UNIT III

ASSIGNMENT SHEET - ANSWERS

1. a. Two-stator windings
   b. Auxiliary winding connected in series with capacitor
   c. Squirrel cage windings
   d. Starting winding disconnects at 3/4 speed
   e. Operates as an induction motor

2. a. Starts with two phase motor action
   b. Has low to moderate starting torque
   c. High starting current
   d. Low in coil

3. a. Starts by motion of a magnetic field
   b. Low coil; low maintenance
   c. Low starting torque

4. a. High starting torque and low starting current
   b. Operates at constant speed
   c. At certain speed centrifugal device short circuits communtator seqments.
   d. Operates as induction motor.

5. a. Can operate either as AC or DC motor
   b. High speed, small sizes
   c. Consist of salient pole stator called the field and wound rotor called armature.

6. a. Requires heavy starting current
   b. No speed control
   c. Motor heating on repeated starts
   d. Limited slip
   e. Less maintenance

7. a. Sparking very possible
   b. Low starting current
   c. Adjustable speed
   d. Highest starting torque
   e. Speed control up to 50%

A.C. MOTORS

UNIT III

ANSWERS TO TEST

1. a. 2
   b. 9
   c. 4
   d. 15
   e. 7
   f. 12
   g. 6
   h. 14
   i. 20
   j. 11
   k. 3
   l. 19
   m. 19
   n. 1
   o. 10
   p. 16
   q. 18
   r. 13
   s. 5
   t. 17
   u. 8
   v. 21

2. a. The motor has at least one capacitor in series with the starting winding.

   b. There are squirrel-cage windings in the rotor.

   c. The capacitor start motor ranges in size from fractional to 5 h.p. and has high starting torque.

   d. The permanent-split capacitor motor has low starting torque but is quiet running and the speed is easily reversed and controlled.

   e. The two valve capacitor motor has two sets of windings and capacitor with the auxiliary set used for starting. This motor ranges in size from 5-20 h.p. and features quiet running and limited speed control with high starting torque.

3. a. This low cost motor is available in fractional sizes (1/20-½ h.p.).

   b. It is used widely on small constant speed loads.

   c. The motor has low to moderate starting torque due to two sets of windings with the auxiliary set dropping out at around 75% speed.

   d. This motor is not good for frequent starting and stopping.

4. a. This low cost motor is available in extremely small sized (1/50-¼ h.p.).

   b. Starting torque is developed from shaded windings around a portion of each core in addition to the normal windings.

   c. This low-maintenance motor is very inefficient and has a low starting torque.

TEST

5. a. This wound rotor has a commutator and a set of brushes.

   b. The motor has high-starting torque and low-starting current.

   c. The commutator and brushes are short circuited at a less than normal speed allowing the motor to become an induction motor.

   d. This motor is made in sizes up to 15 h.p. and is used to start heavy loads easier than capacitor motors.

6. a. This motor can be operated either as an AC or DC motor.

   b. Typically the small motor has high speed.

   c. The motor is built like a series motor therefore the speed increases as the load decreases (it will run away at no load).

7. a. This motor is essentially a constant-speed motor with variations under load.

   b. Three basic NEMA (B, C and D) designs which decide a motor torque, speed, current, and slip are obtained through rotor slip design.

   c. Through rotor design and 60 hertz 3-phase AC current these motors can be adopted to most uses.

   d. These motors are simpler, more rugged, more easily maintained and less expensive.

   e. Multi-speed squirrel-cage motors have several speeds which are obtained by a selector switch which selects effective poles or separate stator windings.

8. a. This motor differs from the squirrel cage in that the rotor is equipped with windings instead of bars.

   b. Leads from the windings are brought to external variable resistors to provide starting or speed regulation.

   c. Torque can also be controlled by varying the external rotor resistance.

   d. This motor can accelerate heavy loads gradually and smoothly.

   e. Due to the complexity the motor has higher initial cost.

ELECTRIC MOTORS AND CONTROLS

UNIT IV

A.C. CONTROLS

A.C. CONTROLS

UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to distinguish between the six types of starters; know when to use full or reduced voltage starting, and wire controllers to different types of motors using wiring diagrams. This knowledge will be shown by completing lab sheets and unit text with a minimum score of 80%.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with A.C. motor controls to their correct definition.
2. Name three conditions necessary to use full voltage starting.
3. Name three ways of braking and examples of each.
4. Name three uses of motor reversing.
5. Distinguish between five basic speed characteristics.
6. Classify control devices as to whether they are primary or pilot control devices.
7. Connect a full voltage starter to a 3-phase motor.
8. Discuss reasons to choose reduced-voltage starting over full voltage starting.
9. Connect a reduced voltage autotransformer to a 3-phase motor.
10. Connect a resistance starter to a wound-rotor motor.
11. Connect a part winding reduced-voltage starter to a wye connected motor.
12. Connect a reduced-voltage wye-delta starter to a 3-phase delta connected motor.
13. Connect a solid state starter with a 3-phase motor.

14. Demonstrate the ability to

    a. Wire a magnetic across the line starter with a limit switch.

    b. Wire a 3-phase reversing contactor.

    c. Wire a part-winding starter for a wye-connected motor.

A. C. CONTROLS

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide student with objective sheet.

   B. Provide students with information, assignment, and lab sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information, assignment, and lab sheets.

   F. Demonstrate correctly A. C. controls to A. C. motors.

   G. Summarize techniques for correcting A. C. controls.

   H. Assist students in wiring controllers to A. C. motors.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Study information sheets.

   C. Complete assignment sheets.

   D. Complete lab sheets.

   E. Take test.

A. C. MOTORS CONTROLS

UNIT IV

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Information sheet.

   C. Assignment sheets.

   D. Lab sheets.

   E. Test.

   F. Answers to assignment sheets.

   G. Answers to test.

II. References

A. Anderson, Leonard R., Electric Machines and Transformers, Reston, Virginia. Reston Publishing Co., 1981.

B. Hubert, Charles I., Preventive Maintenance of Electrical Equipment, New York, New York, McGraw-Hill, 1979.

C. McIntyre, R. L., Electric Motor Control Fundamentals, New York, New York, McGraw-Hill, 1974.

D. Nadon-Gelmine-McLaughlin, Industrial Electricity, Albany, New York, Delmar Publishers, 1984.

E. Richardson, Donald V., Rotating Electric Machinery & Transformers Technology, Reston, Virginia, Reston Publishing Co., 1982.

F. Rochis - Mazur, Electrical Motor Controls, Alsip, IL, American Technical Publishers, Inc., 1982.

G. Rosenburg, Robert, Electric Motor Repair, New York, New York, Holt, Renehart and Winston, 1970.

UNIT IV

INSTRUCTIONAL MATERIALS

H. Sutton, Mack C., Electric Motor Repairman, Austin, Texas, Instructional Material Services, University of Texas, 1973.

III. Additional Material

A. Motor and Motor Controls, New York, New York, The Electrification Council, 1975.

B. Rotating Electrical Machinery, Vincennes, Indiana, Crow Universal Scientific Company Inc., 1954.

A.C. CONTROLS

UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Directing controller--a controller that directs the motor to perform certain functions.

B. Protecting controller--controls that protect a motor and circuit against abnormal conditions.

C. Full voltage starter--a starter that starts the motor by connecting the motor across the line by closing a main switch.

D. Brake--an electromechanical friction device to stop and hold a load.

E. Contactor--a device to establish or interrupt an electric power circuit repeatedly.

F. Drum switch--switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or surfaces on the periphery of a rotating cylinder.

G. Dynamic braking--breaking accomplished by using the motor as a generator, taking it off the line and applying an energy dissipating resistor to the armature.

H. Full load torque--torque necessary to produce rated horsepower at full load speed.

I. Manual controller--electric controller operated by mechanical or manual means.

J. Pilot device--directs operation of another device.

K. Plugging--braking by reversing the line voltage or phase sequence.

L. Synchronous speed--motor rotor and A.C. rotating magnetic field in step or unison.

II. Three conditions necessary for full voltage starting are:

A. Motor must be able to withstand the mechanical forces of full voltage starting.

B. Driven equipment must be able to withstand starting and acceleration forces.

C. The power system must be capable of delivering voltage without causing excessive voltage dips.

INFORMATION SHEET

III. Braking can be accomplished by

A. Coasting by disconnecting the current; used on fans, blowers, and compressors.

B. Electrical by using the motor and counter torques set up within the motor.

C. Mechanical used to complete a stop or provide back-up protection and holding of a load.

IV. Reversing the direction of a motor is used in such application as elevator, conveyors, and automatic drills.

V. Five basic speed characteristics are

A. Constant--steady speed regardless of load changes (AC generally).

B. Varying--slow down as load increases and speed up as load decreases (AC generally).

C. Adjustable--infinite speeds and once set remains essentially constant (DC generally).

D. Adjustable-varying--selectable speed but decreasing with increasing load and increasing as the load decreases.

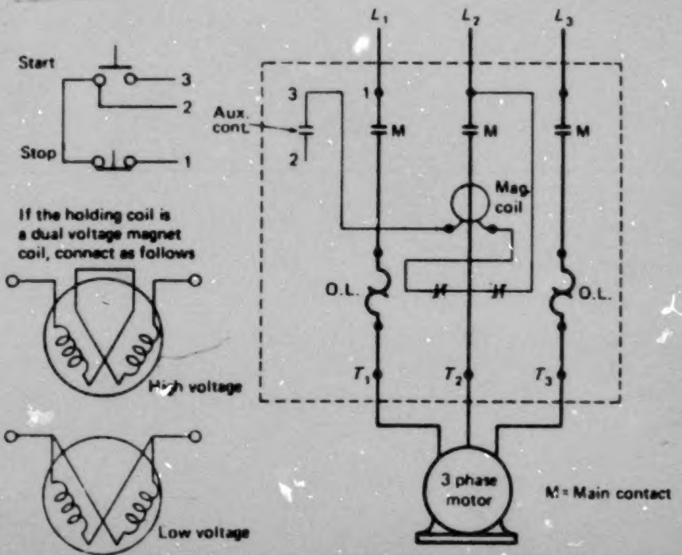
E. Multispeed--once set on one of 2, 3 or 4 speeds, the speed remains constant (AC generally).

VI. Classify devices as to whether they are primary control or pilot control device

A. A magnetic across the line starter is a primary control device.

B. A toggle switch that controls the magnetic starter is a pilot control device.

VII. Connecting a full voltage starter to a 3-phase motor.


Start
3
2
1
Stop
Aux. cont.
3
2
L_1
L_2
L_3
1
M
M
M
Mag. coil
O.L.
O.L.
T_1
T_2
T_3
3 phase motor
M = Main contact
If the holding coil is a dual voltage magnet coil, connect as follows
High voltage
Low voltage

INFORMATION SHEET

A. Magnet coil closes main contacts upon being energized.

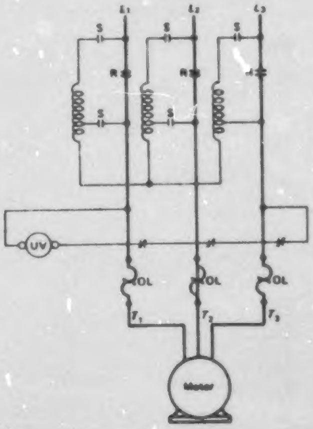
B. Auxiliary coil closes when magnet coil is energized to maintain current in the magnetic coil.

C. Dual voltage coils are for operating, either on high or low voltage.

D. Three-phase starters are equipped with three overload relays if they are in inaccessible places and without other protected means.

VIII. Reduced voltage starting may be necessary if the large demand for full voltage current causes problems back into the power lines. Another reason may be because the motor has no induced EMF at the instant of starting and reduced voltage may be needed. Also, there may not be a need for high torque therefore low-torque or reduced voltage will do.

IX. Connecting a reduced voltage autotransformer to a 3-phase motor



A. The autotransformer is provided with tape for starting the motor at 65%-80% of line voltage.

B. For motor above 50 h.p., NEMA require that a tap be provided for starting at 50% line voltage.

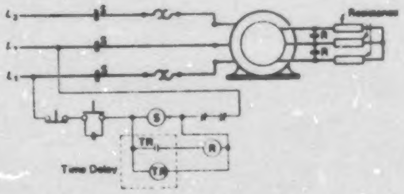
C. Closed-circuit transistor method prevents high transient current and torque when the run contactor is closed because the motor stays connected to the line.

D. Open-circuit transition has starting contactors which are energized first. After the motor is accelerated and the transition to the run contactors is made, the motor is momentarily disconnected from the power supply.

INFORMATION SHEET

E. A major disadvantage of the autotransformer is that it provides a higher torque than most other methods.

X. Connecting a resistance starter to a wound-rotor motor



A. This type of motor is always started with all the resistances in the circuit and full voltage.

B. Pressing the start button energize coils S and TR which places the stator directly across the line and the rotor in series with the resistance.

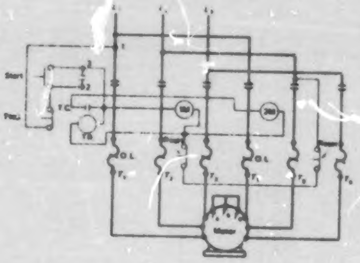
C. After a time delay, coil R is energized cutting the starting resistance out of the rotor circuit.

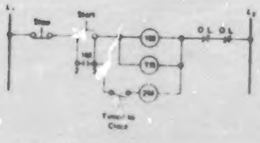
D. This starter does not have as high a torque efficiency as the autotransformer method and requires more current.

E. Resistance-starting and wound-rotor are especially necessary in unusually reverse starting restrictions.

F. Starting currents are lower than in other motor types.

XI. Connecting a part-winding reduced-voltage starter to a wye connected motor





INFORMATION SHEET

A. Part of the 3-phase motor is energized first.

B. The remainder of the winding is energized in one or more steps.

C. Pressing the start button energize the 1m contactor and the time-delay-relay TR causing the motor to run 1/2 the winding.

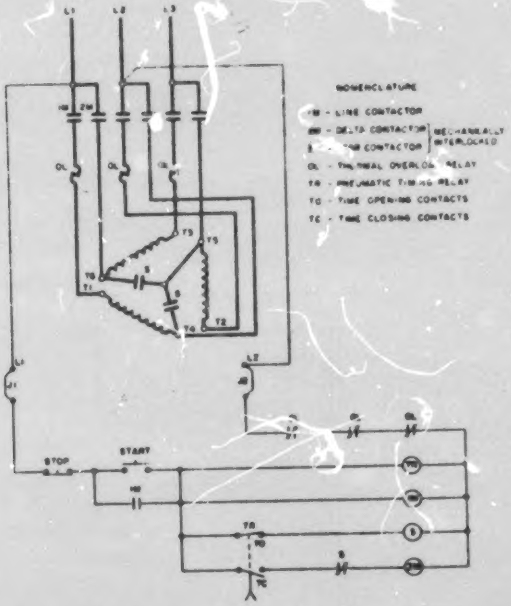
D. After time has run out TR closes causing 2m contactor to close connecting the power to the second half of the winding.

E. Because starting torque is reduced accelerating time is increased.

F. Good where a low power system is available such as in residential and small commercial areas.

G. Used in air conditioning irrigation systems and conveyor systems.

XII. Connecting a reduced-voltage wye-delta starter to a 3-phase dalta connected motor


L1
L2
L3
1M
2M
OL
OL
OL
T3
T5
T6
T1
S
S
T4
T2
L1
J1
L2
J2
OL
OL
OL
STOP
START
TR
1M
1M
TR
TO
S
S
TC
2M
NOMENCLATURE
1M - LINE CONTACTOR
2M - DELTA CONTACTOR
S - STAR CONTACTOR
MECHANICALLY INTERLOCKED
OL - THERMAL OVERLOAD RELAY
TR - PNEUMATIC TIMING RELAY
TO - TIME OPENING CONTACTS
TC - TIME CLOSING CONTACTS

NOTE FOR SEPARATE CONTROL REMOVE JUMPERS J1 AND J2

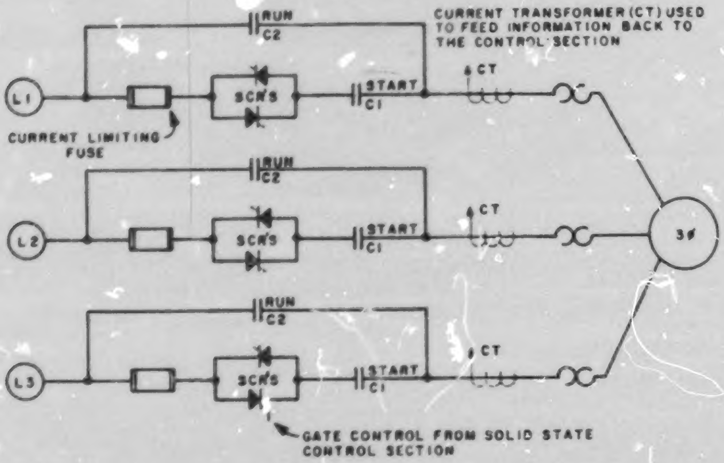
A. This starter is of the open transition type as there is a momentary disconnection of the motor from the line during changeover from item to delta connection.

B. Pressing the start button energize S, IM, and TR. S contractor connects T, T2 and T3 causing the motor to start as a wye motor.

C. After time runs out the TO opens dropping S and TC closes energizing 2m. 2m applies the line to T4, T5, and T6, causing the motor to mill at full voltage.

INFORMATION SHEET

XIII. Connecting a solid slab starter and a 3-phase motor


RUN C2
CURRENT TRANSFORMER (CT) USED TO FEED INFORMATION BACK TO THE CONTROL SECTION
L1
L2
L3
SCR'S
START C1
CT
CURRENT LIMITING FUSE
3ϕ
GATE CONTROL FROM SOLID STATE CONTROL SECTION

A. The start contactors C1 are in series with the SCR and the run contactors C2 are in parallel with the SCR.

B. When the starter is energized, the start contacts C1 close and the acceleration of the motor is controlled by phasing on the SCR.

C. The SCR's control the motor until it approaches full speed at which time the run contacts of C2 close connecting the motor directly to the line.

D. This starter provides smooth stepless acceleration.

E. It is used in starting of conveyors, compressors and pumps.

F. The SCR control motor voltage, current and torque drive acceleration.

G. This method offers the most control over a wider range but is relatively very expensive.

A. C. CONTROLS

UNIT IV

LAB SHEET #1--MAGNETIC ACROSS THE LINE, STARTER WITH A LIMIT SWITCH

I. Equipment and materials

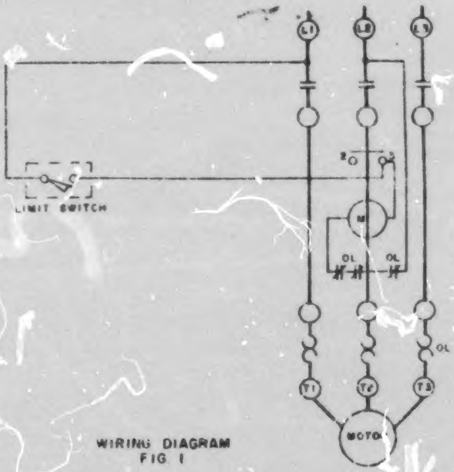
- A. 220 3-phase power supply
- B. 1 h.p. 3-phase motor
- C. 1 limit switch
- D. Magnetic starter
- E. #14 solid copper insulated wire
- F. Multimeter

II. Procedure

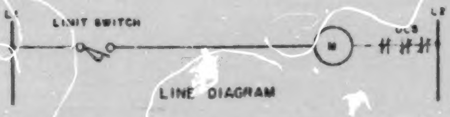
A. Be sure the power source is off.

B. Complete the circuit as shown in the wiring diagram of Figure 1.

FIGURE 1 LIMIT SWITCH CONTROLS MAGNETIC STARTER



WIRING DIAGRAM
FIG. 1



LINE DIAGRAM

C. Check the continuity of the control circuit using a multimeter (NOTE: Have the instructor check circuit and power sources).

D. Activate the limit switch. The motor should run.

E. Disconnect the power source to simulate a power failure.

G. Release the limit switch. The motor should stop.

LAB SHEET

H. Press the "start" button. The motor should run in the reverse direction.

I. Press the "stop" button. The motor should stop.

J. Disconnect the power source.
(NOTE: Discuss the results with the instructor).

K. Put the equipment and material away.

A.C. CONTROLS

UNIT IV

LAB SHEET #2--WIRING A 3-PHASE REVERSING CONTACTOR

I. Equipment and materials

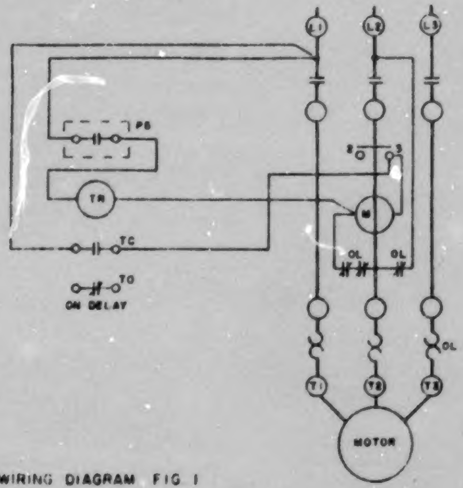
A. 220 3-phase power source
B. Start-stop-reverse module
C. 1 h.p. 3-phase motor
D. #14 solid copper insulated wire

II. Procedure

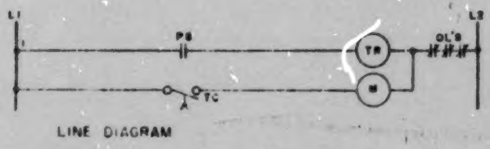
A. Be sure the power source is off.

B. Complete the circuit as shown in the wiring diagram in Figure 1.

FIGURE 1 PUMP OPERATING SYSTEM PROVIDES BACKSPIN AND SURGE PROTECTION ON STOPPING



WIRING DIAGRAM FIG I



LINE DIAGRAM

C. Check the continuity of the circuit using a multimeter. (NOTE: Have the instructor check your circuit.)

D. Move the selector switch to "forward".

E. Press the "start" button. The motor should run.

F. Press the "stop" button. The motor should stop.

G. Move the selector switch to "reverse".

LAB SHEET

H. Reconnect the limit switch. The motor should run.

I. Disconnect the power source.
(NOTE: Discuss your results with your instructor).

J. Put your equipment and material up.

A.C. CONTROLS

UNIT IV

LAB SHEET #3--WIRING A PART-WINDING STARTER FOR A WYE-CONNECTED MOTOR

I. Equipment and materials

A. 220 3-phase power source

B. 1 h.p. 3-phase motor

C. Start-stop module

D. 6 overload relays

E. TR

F. 6 N.O. contacts

G. 1m line contactor

H. 2m line contactors

I. 2 N.C, contactors

J. TR timing relay

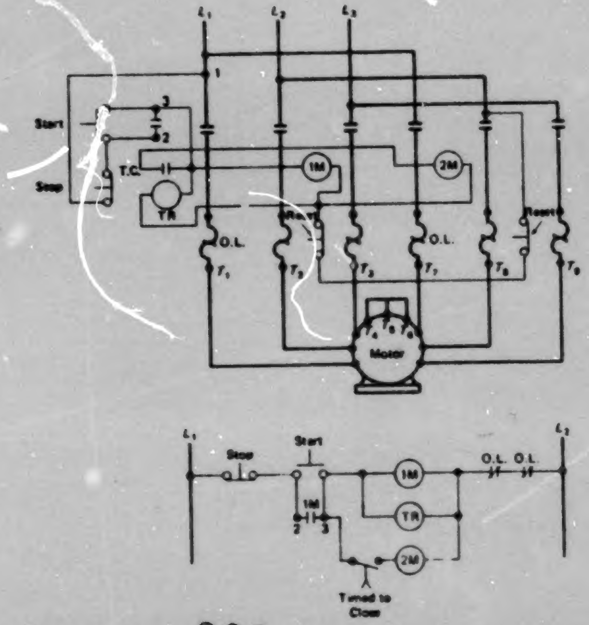
K. SPST N.C. reset contacts

II. Procedure

A. Be sure the power source is off.

B. Connect the diagram as shown in figure 1.

FIGURE 1


L1
L2
L3
1
3
2
Start
Stop
T.C.
1M
2M
TR
Reset
O.L.
O.L.
Reset
T1
T3
T2
T7
T8
T9
Motor
L1
Stop
Start
1M
TR
2M
1M
2
3
O.L. O.L.
L2
Timed to Close

LAB SHEET

C. Check the continuity of the control circuit using a multimeter.
(NOTE: Ask the instructor to check power and circuit connections).

D. Press the "start" button. The motor should begin to start on reduced voltage.

E. After a preset time interval, the motor is connected across the line and should be running on full voltage/full speed.

F. Press the "stop" button momentarily. The motor should begin to stop.

G. Then press the "start" button. The motor should again sequence back to low-voltage speed and again after a preset time, transition to full speed.

H. Press the "stop" button. The motor should stop completely.

I. Disconnect the power source.
(NOTE: Discuss the results with the instructor).

J. Put the equipment and material away.

A.C. CONTROLS

UNIT IV

TEST

NAME____SCORE_______________

1. Match terms associated with A.C. controls to their correct definition. Write the correct numbers in the blanks.

_____a. A controller that directs the motor to perform certain functions.

_____b. An electromechanical friction device to stop and hold a load.

_____c. Controls that protect a motor and circuit against abnormal conditions.

_____d. Directs operation of another device.

_____e. Electric controller operated by mechanical or manual means.

_____f. Torque necessary to produce rated horsepower at full load speed.

_____g. Breaking accomplished by using the motor as a generator, taking it off the line and applying an energy dissipating resistor to the armature.

_____h. Motor rotor and A.C. rotating magnetic field in step or unison.

_____i. Braking by reversing the line voltage or phase sequence.

_____j. A device to establish or interrupt an electric power circuit repeatedly.

_____k. A starter that starts the motor by connecting the motor across the line by closing a main switch.

_____l. Switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or surfaces on the periphery of a rotating cylinder.

1. Directing controller
2. Full voltage starter
3. Manual controller
4. Protecting controller
5. Brake
6. Contactor
7. Drum switch
8. Plugging
9. Pilot device
10. Synchronous speed
11. Full load torque
12. Dynamic braking

2. Name the three conditions necessary to use full voltage starting.

a.

b.

c.

TEST

3. Give three methods of braking and an example of each.

   a.
   b.
   c.

4. Name three uses of motor reversing.

   a.

   b.

   c.

5. List five basic speed characteristics.

   a.
   b.
   c.
   d.
   e.

6. What is the difference between the following control devices:

   a. Pilot--

   b. Control--

7. In a full voltage starter and 3-phase motor, why would it be necessary to have three overload relays?________________________________

8. Discuss the reasons to choose reduced-voltage starting over full-voltage starting.________________________________

TEST

9. What is a major disadvantage of the autotransformer starter?

10. How is reduced voltage starting accomplished in the resistance-starter for a wound-rotor motor?

11. If starting torque is reduced, how is acceleration affected in a part-winding starter and a wye connected motor?

12. In a wye-delta starter connected to a 3-phase motor, what kind of connection during transition between the motor and the line is made?

13. How is acceleration controlled in a solid state starter and a 3-phase motor?

NOTE: Test question #14 are Lab Sheets. They are an important part of this unit. If they have not been completed check with your instructor.

14. Demonstrate the ability to:

    a. Wire across-the-line magnetic starter with a limit switch.

    b. Wire a 3-phase reversing contactor.

    c. Wire a part-winding starter for a wye-connected motor.

15. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

D.C. CONTROLS

UNIT IV

ANSWERS TO TEST

1. a. 1
   b. 5
   c. 4
   d. 9
   e. 3
   f. 11
   g. 12
   h. 10
   i. 8
   j. 6
   k. 2
   l. 7

2. a. Motor must be able to withstand the mechanical forces of full voltage starting.

   b. Driven equipment must be able to withstand starting and acceleration forces.

   c. The power system must be capable of delivering voltage without causing excessive voltage dips.

3. a. Costing by disconnecting the current; used on fans, blowers, and compressors.

   b. Electrical by using the motor and counter torques set up within the motor.

   c. Mechanical used to complete a stop or provide back-up protection and holding of a load.

4. a. Elevators

   b. Automatic drills

   c. Conveyors

5. a. Constant--steady speed regardless of load changes (AC generally).

   b. Varying--slow down as load increases and speed up as load decreases (AC generally).

   c. Adjustable--infinite speeds and once set remains essentially constant (DC generally).

   d. Adjustable-varying--selectable speed but decreasing with increasing load and increasing as the load decreases.

   e. Multispeed--once set on one of 2, 3 or 4 speeds, the speed remains constant (AC generally).

ANSWERS TO TEST

6. a. A magnet across the line starter is a primary control device.

   b. A toggle switch that controls the magnetic starter is a pilot control device.

7. a. Magnet coil closes main contacts upon being energized.

   b. Auxiliary coil closes when magnet coil is energized to maintain current in the magnetic coil.

   c. Dual voltage coils are for operating, either on high or low voltage.

   d. Three-phase starters are equipped with three overload relays if they are in inaccessible places and without other protected means.

8. Reduced voltage starting may be necessary if the large demand for full voltage current causes problems back into the power lines. Another reason may be because the motor has no induced EMF at the instant of starting and reduced voltage may be needed. Also, there may not be a need for high torque therefore low-torque or reduced voltage will do.

9. A major disadvantage of the autotransformer is that it provides a higher torque than most other methods.

10. a. This type of motor is always started with all the resistances in the circuit and full voltage.

    b. Pressing the "start" button energizes coils S and TR which places the stator directly across the line and the rotor in series with the resistance.

    c. After a time delay, coil R is energized cutting the starting resistance out of the rotor circuit.

    d. This starter does not have as high a torque efficiency as the autotransformer method and requires more current.

    e. Resistance-starting and wound-rotor are especially necessary in unusually reverse starting restrictions.

    f. Starting currents are lower than in other motor types.

11. Accelerating time is increased.

ANSWERS TO TEST

12. There is a momentary disconnection of the motor from the line during changeover from item to delta connection.

13. Silcone Control Rectifier (SCR).

DIGITAL ELECTRONICS

UNIT I

DIGITAL FUNDAMENTALS

DIGITAL FUNDAMENTALS

UNIT I

OBJECTIVE

After completing this unit, the student should be able to convert decimal numbers to binary, BCD, and ASCII number systems. The student should also be able to state where and how digital devices are used. This knowledge will be shown by completing assignment sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with digital fundamentals to their correct definition.
2. Distinguish between analog and digital devices.
3. Name industries where digital devices are used.
4. List advantages of digital devices.
5. Convert a decimal number to a binary number.
6. Convert a binary number to a decimal number.
7. Calculate the size of a binary number.
8. Identify whether a number is base two or base ten.
9. Convert a decimal number to a binary coded decimal numbers.
10. Convert a symbols to an ASCII number.
11. State three different ways of representing data.
12. Construct representations for parallel and serial data transmission.
13. Name two types of logic circuits.

DIGITAL FUNDAMENTALS

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

- A. Provide students with objective sheet.
- B. Provide student with information and assignment sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information and assignment.
- F. Demonstrate conversion of numbers from one base to another.
- G. Demonstrate use of the ASCII Lathe.
- H. Summarize the usefulness of digital devices.
- I. Give test.

II. Student

- A. Read objectives
- B. Study information sheets.
- C. Complete assignment sheets
- D. Take test.

DIGITAL FUNDAMENTALS

UNIT I

INSTRUCTIONAL MATERIALS

I. Included in this unit

  A. Objective sheet.

  B. Information sheets.

  C. Assignment sheets.

  D. Test.

  E. Answers to assignment sheets.

  F. Answers to test

II. References

  A. Pasahow, Edward I., Learning Digital Electronics Through Experiments, New York, New York, McGraw-Hill, 1982

  B. Pasahow. Edward I., Digital Integrated Circuits, New York New York McGraw-Hill Book Co. 1979.

  C. Leach, Donald P., Experiments In Digital Principle, New York, New York, McGraw-Hill Book Co. 1981.

  D. Miller, Michael A., Digital Computers Electronics, New York, New York, McGraw-Hill Book Co. 1983

III. Other References

  Digital Techniques Vol. I and II. Benton Harber, Michigan, Heath Company 1983

DIGITAL FUNDAMENTALS

UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Analog signal - voltage or current that varies smoothly.

B. Digital signal - voltage level pulses that vary as discrete steps.

C. Bit - one binary digit.

D. Byte - a group of bits make up a byte or a word.

[illegible] Binary number system - a number system that consists of the two numbers 0 and 1.

F. Base - a number that tells how many numbers are in a number system.

G. Positioned number system - each position in a number carries a specific weight. Example: <u>Base ten</u> -

$(6x10^2)+(3x10')+(2x10^0)$
= 600 + 30 + 2
= 632

<u>Base two</u> -

$(1x2^3)+(0x2^2)+(1x2^1)+(1x2^0)$
= 8 + 0 + 2 + 1
= 1[illegible]

<u>Base two</u> (fractional) -

$(1x2^2)+(0x2^1)+(1x2^0)+(1x2^{-1})+(1x2^{-2})$
= 4 + 0 + 1 + .5 + .25
= 5.75

H. Binary-coded decimal system - a system that represents a decimal digit with a four digit binary number. Example:

```
      8     3
83 = 1000  001
```

I. Excess 3 code - a system that adds a 3 to the decimal digit then converts it to four binary digits. Example:

```
24     2+3 = 5
       4+3 = 7

57 = 01000111
```

INFORMATION SHEET

J. Gray Code - a system that converts decimal to binary but by changing only one bit (Transparency #1). Example:

FIGURE 1:

THE GRAY CODE

DECIMAL	GRAY	PURE BINARY
0	0000	0000
1	0001	0001
2	0011	0010
3	0010	0011
4	0110	0100
5	0111	0101
6	0101	0110
7	0100	0111
8	1100	1000
9	1101	1001
10	1111	1010
11	1110	1011
12	1010	1100
13	1011	1101
14	1001	1110
15	1000	1111

ASCII Code - this system known as the American Standard Code for Information Interchange is a BCD Code used in digital computers a data communication. It is a 7 digit binary code (Transparency #2). Example: D = 1000100

K. Positive and negative logic - logic representation. When the most positive voltage is assigned the logic one. This representation is called positive logic. Example:

Positive	Negative
binary 1 = 3.4V	binary 1 = 0.2V
binary 0 = 0.2V	binary 0 = 3.4V

L. Most - significant - bit (MSB) -- the left most bit in a binary number.

M. Leart - significant - bit (LSB) -- the right most bit in a binary number.

INFORMATION SHEET

II. Distinguish between analog and digital devices.

A. Analog

Voltmeter
Volume control
Speedometer

B. Digital

Lamp switch
Channel selector on a TV
Money

III. Industries where digital devices are used are:

Computers - IBM
Communications - telephone company
Telemetry - satellites
Test instruments - digital voltmeter
Industrial controls - flow rates
Consumer electronics - TV

IV. Advantages of using digital devices:

A. Lower cost
B. Greater precision
C. Greater range
D. Greater stability
E. Easier to use
F. Automated operation
G. Greater problem solving

V. Convert a decimal number to a binary number by repeatedly dividing the number by 2. Example: convert 238

$238 \div 2 = 119$ 0 LSB
$119 \div 2 = 59$ 1
$59 \div 2 = 29$ 1
$29 \div 2 = 14$ 1
$14 \div 2 = 7$ 0
$7 \div 2 = 3$ 1
$3 \div 2 = 1$ 1
$1 \div 2 = 0$ 1 MSB

Therefore 238 = 11101110

INFORMATION SHEET

VI. Convert a binary number to a decimal number by setting the binary number up in its positional notation. Example: convert 11001.01

$$(1x2^{4})+(1x2^{3})+(0x2^{2})+(1x2^{0}) \text{ o } (0x2^{-1})+(1x2^{-2})$$

$$= 16 + 8 + 0 + 0 + 1 + 0 + 0.25$$
$$= 25.25$$

VII. Binary number sizes can be calculated by using the formula $N= 2^{n}$

Where N = total number of possible different numbers.
n = total number of bits in a word (byte).

Example: a. 2 bit bytes can represent ($2^2 = 4$) four different combinations

Decimal	Binary
0	00
1	01
2	10
3	11

b. 8 bit byte can represent ($2^8 = 256$) 256 different combinations

VIII. By using a subscript a number can be identified as to whether it is binary (2) or decimal (10). Example:

$$10_2 = 2_{10}$$
$$10_{10} = 10_{10}$$

IX. Convert a decimal number to a binary coded decimal number by using a four digit binary number to represent each decimal digit. Example:

$$18_{10} = 00011000_2$$
$$406_{10} = 0100\ 0000\ 0101_2$$

X. Convert a decimal number to an ASCII number by using the ASCII Table.
Example: Using Figure 2 8 = 0111000

FIGURE 2.

TABLE IV
AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE

	COLUMN	0	1	2	3	4	5	6	7
ROW	BITS 4321 / 765	000	001	010	011	100	101	110	111
0	0000	NUL	DLE	SP	0	@	P	`	p
1	0001	SOH	DC1	!	1	A	Q	a	q
2	0010	STX	DC2	"	2	B	R	b	r
3	0011	ETX	DC3	#	3	C	S	c	s
4	0100	EOT	DC4	$	4	D	T	d	t
5	0101	ENQ	NAK	%	5	E	U	e	u
6	0110	ACK	SYN	&	6	F	V	f	v
7	0111	BEL	ETB	'	7	G	W	g	w
8	1000	BS	CAN	(	8	H	X	h	x
9	1001	HT	EM	)	9	I	Y	i	y
10	1010	LF	SUB	*	:	J	Z	j	z
11	1011	VT	ESC	+	;	K	[	k	{
12	1100	FF	FS	,	<	L	\	l	¦
13	1101	CR	GS	-	=	M	]	m	}
14	1110	SO	RS	.	>	N	^	n	~
15	1111	SI	US	/	?	O	—	o	DEL

Explanation of special control functions in columns 0, 1, 2 and 7.

NUL	*Null*	*DLE*	*Data Link Escape*
SOH	*Start of Heading*	*DC1*	*Device Control 1*
STX	*Start of Text*	*DC2*	*Device Control 2*
ETX	*End of Text*	*DC3*	*Device Control 3*
EOT	*End of Transmission*	*DC4*	*Device Control 4*
ENQ	*Enquiry*	*NAK*	*Negative Acknowledge*
ACK	*Acknowledge*	*SYN*	*Synchronous Idle*
BEL	*Bell (audible signal)*	*ETB*	*End of Transmission Block*
BS	*Backspace*	*CAN*	*Cancel*
HT	*Horizontal Tabulation (punched card skip)*	*EM*	*End of Medium*
LF	*Line Feed*	*SUB*	*Substitute*
VT	*Vertical Tabulation*	*ESC*	*Escape*
FF	*Form Feed*	*FS*	*File Separator*
CR	*Carriage Return*	*GS*	*Group Separator*
SO	*Shift Out*	*RS*	*Record Separator*
SI	*Shift In*	*US*	*Unit Separator*
SP	*Space (blank)*	*DEL*	*Delete*

INFORMATION SHEET

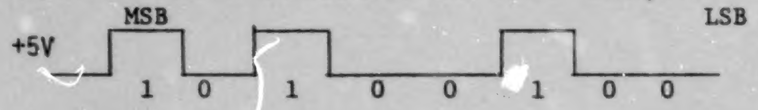
XI. Three ways of representing data are:

a. switches - closed could equal a one, open a zero

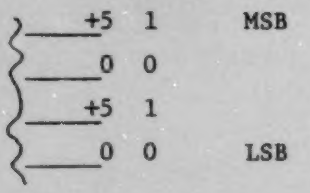
b. Transistor - conducting could equal a one, non-conducting a zero

c. Magnetic core - magnetized could equal a one, unmagnetized a zero

XII. Data can be transmitted by a serial or parallel mode. The serial mode transmits one bit at a time over one line. Example:



Parallel transmission takes place with all bits of a byte being transmitted at once over many lines. Example:



XIII. There are two basic types of logic circuits. Decision making circuits are called gates while memory circuits are called flip flops.

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #1 - CONVERTING DECIMAL NUMBERS TO BINARY NUMBERS.

Show your work.

1. 28_{10}

2. 99_{10}

3. 47_{10}

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #2 - CALCULATE THE SIZE OF A BINARY NUMBER

To determine the largest decimal number that can be represented by a byte, take the number of bits in the byte (n) and the total different numbers (N) in the number system and use this formula N^n.

What is the largest decimal number that can be represented by the following:

1. 8 bit byte, 16 different numbers.

2. 16 bit byte, 2 different numbers.

3. 32 bit byte, 2 different numbers.

4. 32 bit byte, 16 different numbers.

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #3 - CONVERT A DECIMAL NUMBER TO A BINARY CODED DECIMAL (BCD) NUMBER.

Convert the following decimal numbers to BCD numbers.

1. 58 =

2. 2096 =

3. 4 =

4. 256 =

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #4 - CONVERT A DECIMAL NUMBER TO AN ASCII NUMBER

Convert the following symbol numbers to ASCII numbers using the chart on Information Sheet, Item X.

1. 37

2. DAY =

3. $4.15 =

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #5 - SERIAL AND PARALLEL TRANSMISSION REPRESENTATION

Represent the following numbers (BCD) in both serial and parallel transmission.

1. 1101_2

2. 10101010_2

3. 38

DIGITAL FUNDAMENTALS

UNIT I

TEST

NAME____SCORE_________________

1. Match terms associated with digital fundamentals to their correct definition. Write the correct numbers in the blank.

_____a. Each position in a number carries a specific weight.

_____b. A system that adds a 3 to the decimal digit then converts it to four binary digits.

_____c. One binary digit.

_____d. Voltage level pulses that vary as discrite steps.

_____e. A number that tells how many numbers are in a number system.

_____f. A system that converts decimal to binary but by changing only one bit.

_____g. A system that represents a decimal digit with a four digit binary number.

_____h. A group of bits make up a byte or a word.

_____i. Voltage or current that varies smoothly.

_____j. A number system that consists of the two numbers 0 and 1.

_____k. When the most positive voltage is assigned the logic one.

_____l. The right most bit in a binary number.

_____m. The left most bit in a binary number.

1. Most-significant-bit (MSB)
2. Gray Code
3. Binary-coded decimal system
4. Base
5. Bit
6. Digital signal
7. Byte
8. Analog signal
9. Excess 3 code
10. Leart-significant bit (LSB)
11. Positioned number system
12. Positive and negative logic-logic represention
13. Binary number system

2. Distinguish between analog and/or digital devices by labeling the following "a" for analog and "d" for digital:

_____a. Ammeter

_____b. Frequency counter

_____c. Gas gage

_____d. Toggle switch

_____e. Big Ben the clock

_____f. Tone control

TEST

3. Name five different industries where digital devices are used.

a.

b.

c.

d.

e.

4. List at least five advantages of digital equipment.

a.

b.

c.

d.

e.

5. Convert the following decimal numbers to binary numbers:

a. 88

b. 53

TEST

6. Convert the following binary numbers to decimal numbers.

   a. 1111_2 =

   b. 101011_2 =

   c. 11111010_2 =

   d. 10000_2 =

7. Calculate the number of different binary numbers we can have with

   a. an 8 bit byte; ____________________

   b. a 32 bit byte; ____________________

TEST

8. Identify whether the following numbers are binary or decimal

a. 1010_2 .

b. 1010_{10} .

c. 383_{10} .

d. 1111_2 .

9. Convert the following decimal numbers to BCD numbers.

a. 888 =

b. 1 =

c. 202 =

TEST

10. Convert the following symbols to ASCII numbers using your ASCII Chart

a. 61

b. DATE

c. +24

11. State whether the following are

M. mechanical

E. electronic

B. magnetic

Ways of representing data

_____a. toggle switches

_____b. solenoids

_____c. diodes

TEST

12. Construct both parallel and serial representation for the following binary numbers.

    a. 11001100_2

    b. 10111001_2

13. Name two types of logic switches.

    a.

    b.

14. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #1 ANSWERS

1. 11100_2
2. 1100011_2
3. 101111

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #2 - ANSWERS

1. 42, 94, 967, 300
2. 65, 536
3. 42, 94, 967, 300
4. $\approx 3.4028236\text{x}10^{38}$

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #3 - ANSWERS

1. 0101 1000
2. 0010 0000 1001 0110
3. 0100
4. 0010 0101 0110

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET # 4 - ANSWERS

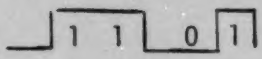
1. 0110011 0110111
2. 1000100 1000001 1011001
3. 0100100 0110100 0101110 0110001 0110101

DIGITAL FUNDAMENTALS

UNIT I

ASSIGNMENT SHEET #5 - ANSWERS

1.



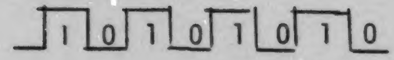
______+5 1

______+5 1

______0 0

______+5 1

2.



_____+5 1

_____0 0

_____+5 1

_____0 0

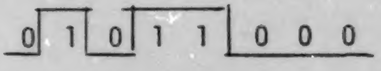
_____+5 1

_____ 0 0

_____+5 1

_____0 0

3.



_____0

_____+5

_____0

_____+5

_____+5

_____0

_____0

_____0

DIGITAL FUNDAMENTALS

UNIT I

TEST ANSWERS

1. a. 11
   b. 9
   c. 5
   d. 6
   e. 4
   f. 2
   g. 3
   h. 7
   i. 8
   j. 13
   k. 12
   l. 10
   m. 1

2. a. a,d
   b. a,d
   c. a
   d. d
   e. a
   f. a

3. Answers like:

   Computer - NCR
   Communication - US Army
   Telemetry - long distance controls
   Test instruments - digital frequency counter
   Industrial controls - oil companies
   Consumer electronics - microwave

4. Five of the following:

   Lower cost
   Greater precision
   Greater range
   Greater stability
   Easier to use
   Automated operation
   Greater problem solving

5. a. 1011000_2

   b. 110101_2

6. a. 15
   b. 43
   c. 250
   d. 16

TEST ANSWERS

7. a. 256

   b. 4294967300

8. a. Binary

   b. Decimal

   c. Decimal

   d. Binary

9. a. 100010001000

   b. 1

   c. 1000000010

10. a. 0110110

    b. 1000100 1000001 1010100 100 0101

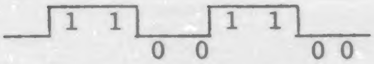
    c. 010100 0110010 0110100

11. a. M

    b. B

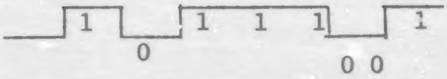
    c. E

12. a.



______+5
______+5
______0
______0
______+5
______+5
______0
______0

b.



______+5
______0
______+5
______+5
______+5
______0
______0
______+5

13. Memory and decision-making.

DIGITAL ELECTRONICS

UNIT II

DIGITAL CIRCUITS

DIGITAL CIRCUITS

UNIT II

OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to wire and test positive OR/AND and negative AND/OR (NAND/NOR) gates and integrated circuits. This knowledge will be shown by completing lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with digital circuits to their correct definitions.
2. Match abbreviations and symbols associated with digital circuits to their correct definitions.
3. Explain how an inverter functions through the use of a truth table.
4. Describe how a simple transistor inverter works.
5. Explain how a three input AND gate functions through the use of a truth table.
6. Describe how a simple diode AND gate works.
7. Explain how a three input OR gate works through the use of a truth table.
8. Describe how a simple diode OR gate works.
9. Explain through the use of a truth table the affect of positive and negative logic.
10. Explain through the use of a truth table the function of a NAND gate.
11. Explain through the use of a truth table the function of a NOR gate.

SPECIFIC OBJECTIVES

12. Explain through the use of logic symbols how AND and OR operations can be performed with NAND and NOR gates.

13. Describe the three basic ways of making integrated circuits.

14. Name the different ways of packaging integrated circuits.

15. Name four different TTL variations.

16. Compare, through a table, the different types of integrated circuits and their characteristics.

17. Demonstrate the ability to

    a. Wire and test the operations of integrated circuit logic inverters.

    b. Wire and test the operation of logic AND and OR gates.

    c. Wire and test the operation of TTL positive and negative logic.

    d. Wire and test the operation of both TTL and CMOS devices in one circuit.

DIGITAL CIRCUITS

UNIT II

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and lab sheets.

   C. Make transparencies.

   D. Discuss unit and specific objective.

   E. Discuss information, assignment, and lab sheets.

   F. Demonstrate the functions AND, OR NAND, NOR gate.

   G. Demonstrate the usefulness of truth table in digital electronic.

   H. Assist student in connecting and troubleshooting integrated circuits.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Study information sheet.

   C. Complete assignment sheet.

   D. Complete lab sheet.

   E. Take test.

DIGITAL CIRCUITS

UNIT II

INSTRUCTIONAL MATERIAL

I. Included in this unit:

- A. Objective sheets.
- B. Information sheets.
- C. Assignment sheets.
- D. Lab sheets.
- E. Test.
- F. Answers to assignment sheets.
- G. Answers to test.

II. References

A. Pasahow, Edward L., Learning Digital Electronics Through Experiments, New York, New York, McGraw-Hill, 1982.

B. Pasahow, Edward I., Digital Integrated Circuits, New York New York, McGraw-Hill Boox Co. 1979.

C. Leach, Donald P., Experiments in Digital Principle, New York, New York, McGraw-Hill Book Co. 1981.

D. Miller, Michael A., Digital Computers Electronics, New York, New York, McGraw-Hill Book Co. 1983.

III. Other References.

Digital Techniques, Vol. I and II. Benton Harbor, Michigan, Heath Company, 1983.

DIGITAL CIRCUITS

UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Combinational circuits - a combination of two or more gates or decision-making elements.

B. Sequential circuits - interconnected combinational circuits and memory elements to make up counters, registers, and tuners.

C. Inverter circuit - a circuit whose output is always the opposite of its input.

D. AND gate - a circuit that has two or more inputs and one output. The output is a binary one only if all inputs are a binary one.

E. OR gate - a circuit that has two or more inputs and one output. The output is a binary one if any input is a binary one.

F. Dual function logic - positive logic is assigning a binary 1 to high voltage and a binary zero to low voltage. Negative logic is assigning a binary 1 to low voltage and a binary 0 to high voltage.

G. NAND gate - a gate derived from inverting the output of an AND gate.

H. NOR gate - a gate derived from inverting the output of an OR gate.

I. Integrated circuit - a semiconductor device that combines transistors, diodes, resistors, and capacitors on a silicon chip.

J. Propagation delay - the measure of the speed of operation of a circuit.

K. Power dissipation - the measure of the amount of power consumed by the components in a logic gate or circuit.

L. Noise immunity - the measure of the susceptibility of a logic circuit to noise pulses on inputs and outputs.

M. Fan out - a number that indicates how many gates may be attached to the output of a digital circuit.

INFORMATION SHEET

N. Temperature range - a reliability rating--military -55° C to + 125° C; commercial 0° C to 70° C.

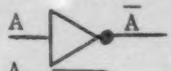
O. Current source logic - when the load appears between the output and the ground of the logic circuit.

P. Current sink logic - when the load appears between the output and the supply voltage.

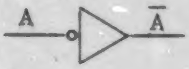
II. Match abbreviations or symbols associated with digital circuits with their correct definitions.

A. The inverse of A (not A) is $\overline{A}$.

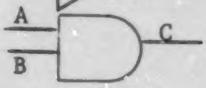
B. The inverter



or

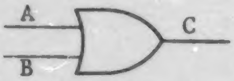


C. The AND gate



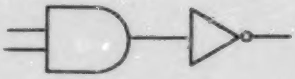
D. AND operation $A \cdot B = C$

E. The OR gate



F. OR operation $A + B = C$

G. The NAND gate



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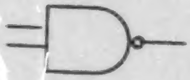
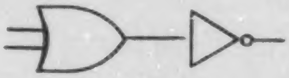


H. The NOR gate



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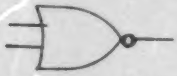


I. SSI - small scale integrated circuits which contain NAND, NOR and flip flops.

J. MSI - medium scale integrated circuits which contain combinational or sequential types.

K. LSI - large scale integrated circuits which contain whole systems of circuits on one chip.

L. The time a pulse takes to go from 10% to 90% of its value $-t_r$.

M. The time a pulse takes to go from 90% to 10% its value $-t_f$.

N. TTL - transistor-transistor logic. - low cost circuit that is used in SSI and MSI elements used for positive logic NAND and negative logic NOR.

O. ECL - emitter coupled logic - a logic circuit that prevents transistor saturation. High speed logical circuit that has a normal output as well as its complement.

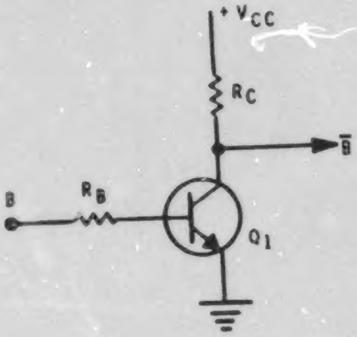
P. MOS - metal oxide semiconductor circuits. Low power, compact but slow in speed.

III. An inverter has two possible states as can be seen through the use of a truth table. Example:

Input	Output
A	$\overline{A}$
0	1
1	0

IV. The simplest inverter is the transistor switching circuit in Figure 1.

FIGURE 1



A transistor logic inverter.

Inverter Operation

--a. With the transistor in cut-off, the supply voltage is available at the output as a binary 1 in positive logic.

--b. With the transistor forward biased as is the case when positive logic 1 is at the input, there is approximately zero volts available to the output or a logic 0.

INFORMATION SHEET

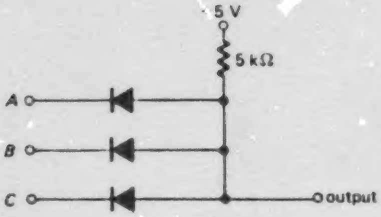
V. A three input AND gate works as indicated by the truth table in Figure 2.

FIGURE 2

Inputs			Outputs
A	B	C	D
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

VI. A simple three input AND gate is shown in Figure 3.

FIGURE 3



Positive logic AND diode gate

The only time the supply voltage is available to the output is when all inputs are binary 1 in positive logic.

INFORMATION SHEET

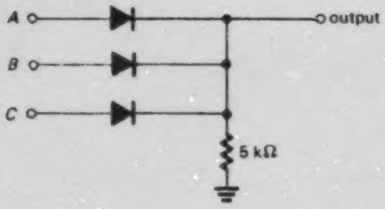
VII. A three position positive logic OR gate works as shown in Figure 4.

FIGURE 4

Inputs			Outputs
A	B	C	D
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

VIII. A simple three input OR gate is shown in Figure 5.

FIGURE 5



Positive logic OR diode gate

For positive logic the output will be a binary one when at least one of the inputs is a binary one.

INFORMATION SHEET

IX. Switching from positive to negative logic by reversing the voltage assignments for a simple divide gate has the affect of changing an OR gate to an AND gate and an AND gate to an OR gate. Example:

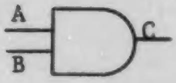
Input		Output
A	B	C
0V	0V	0V
0V	+5V	0V
+5V	0V	0V
+5V	+5V	+5V

Input		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Positive AND

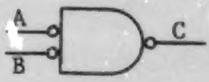
Input		Output
A	B	C
1	1	1
1	0	1
0	1	1
0	0	0

Negative OR



Positive AND
Symbol

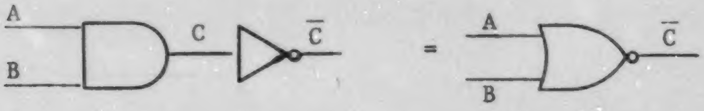
$A \cdot B = C$



Negative OR
Symbol

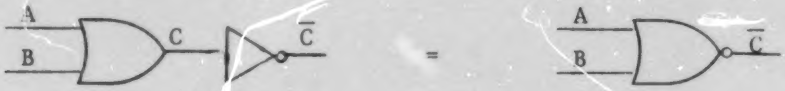
$A + B = C$

X. A NAND gate is gotten by placing an inverter on the output of an AND gate. The output will be reversed so that a binary 0 output will become a binary 1 output. Example:



Inputs		Outputs	
A	B	C	$\overline{C}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

XI. A NOR gate is gotten by placing an inverter on an OR gate. The output will be reversed so that a binary 0 output will become a binary 1 output. Example:

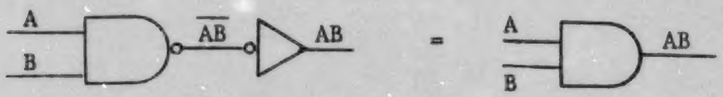


INFORMATION SHEET

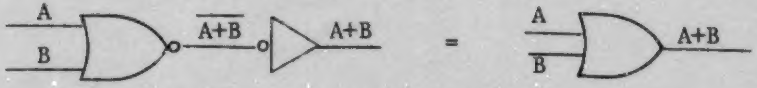
Inputs		Outputs	
A	B	C	$\overline{C}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

XII. An AND or an OR gate may be obtained from a NAND or a NOR gate respectively by placing an inverter on the outputs of the respective gate. Example:

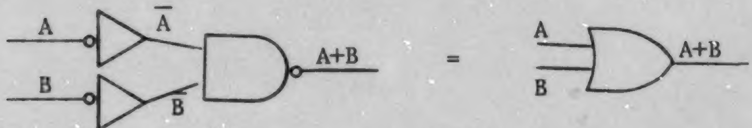
a.


A
B
$\overline{AB}$
AB
=
A
B
AB

b.


A
B
$\overline{A+B}$
A+B
=
A
B
A+B

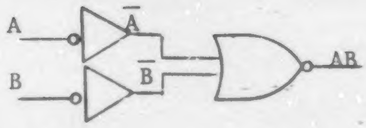
c.

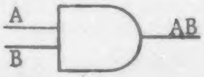

A
$\overline{A}$
B
$\overline{B}$
A+B
=
A
B
A+B

Inputs				Outputs	
A	B	A	B	C	$\overline{C}$=A+B
0	0	1	1	1	0
0	1	1	0	0	1
1	0	0	1	0	1
1	1	0	0	0	1

NOTE: Through the use of inverters on the inputs a NAND gate can be used as an OR gate.

d.





Inputs				Outputs	
A	B	$\overline{A}$	$\overline{B}$	C	$\overline{C}$ = A.B
0	0	1	1	1	0
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	0	1

NOTE: Through the use of inverters on the inputs a NOR gate can be used as an AND gate.

XIII. There are three basic ways of making integrated circuits which are:

a. Monolithic - this integrated circuit has semiconductor material diffused into the base material to form junctions. The MOS and bipolar circuits are constructed on a chip of silicon.

b. Film - Thin and thick films are manufactured by depositing on a ceramic material to four resistors, capacitors, and indicators. Semiconductors are not made this way. This method produces a high quality precision circuit.

c. Hybrid - This method combines monolithic and film methods. Here a variety of different circuits and components can be combined in ways that the other methods can't.

XIV. There are three basic ways of packaging integrated circuits.

a. TO5 can - used to package transistors and a good heat dissipator.

b. Flat pack - used in high density packaging and not good for heat dissipation.

c. Dual in-line package - most popular and come in 8-40 per package.

INFORMATION SHEET

XV. Four TTL variations are:

a. Low power TTL (30-40 nanosecond t_p)

b. High power TTL (0 nanosecond t_p)

c. Schottky TTL (3 nanosecond t_p)

d. Three state TTL (0,1 and open state)

XVI. A table can be used to compare the characteristics of integrated circuits. Example:

Comparison of IC Logic Family Characteristics

Characteristic	TTL	ECL	MOS	CMOS
Fan-out	10	25	20	50+
Cost	low	medium to high	medium to high	low to medium
Power dissipation per gate (mW)	12 to 22	40 to 60	0.2 to 10	0.01 static 1 at 1 MHz
Noise generation	high	low to medium	medium	low medium
Immunity to external noise	good	good	good	very good
Temperature range (°C)	55 to +125 0 to 75	−55 to +125	−55 to +125 0 to 75	−55 to 125 40 to 85
Typical supply voltage (V)	+5	−5.2	−27, −13 (PMOS) +5 (NMOS)	+1.5 to 18
Avg. propagation delay per gate (ns)	3 to 12	1 to 2	300 (PMOS) 50 (NMOS)	70
Avg. clock rate (MHz)	15 to 120	200 to 1000	2 (PMOS) 5 to 10 (NMOS)	5 to 10

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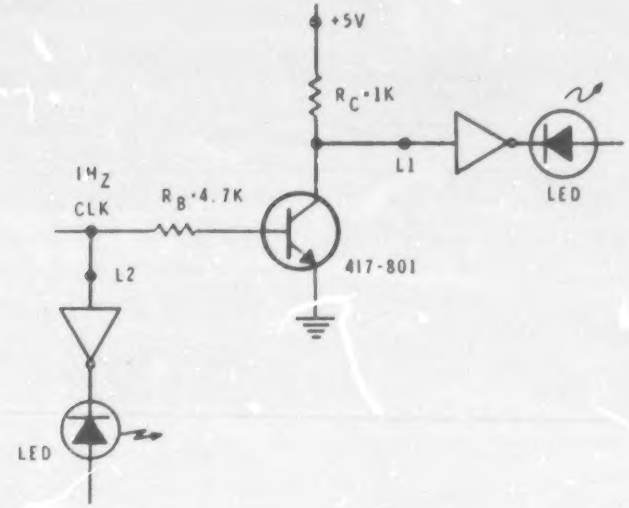
DIGITAL CIRCUITS

UNIT II

ASSIGNMENT SHEET #1 - TRANSISTORS USED AS INVERTERS

1. Use Figure 1 and a truth table to explain how an inverter works.

FIGURE I


+5V
R_C=1K
L1
LED
1Hz
CLK
R_B=4.7K
417-801
L2
LED

INPUT	OUTPUT
V_i	V_o

ASSIGNMENT SHEET #1

2. Discuss how a transistor works as an inverter.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT SHEET #2 - THREE INPUT AND GATES USING DIODES

1. Explain, through the use of a truth table how a 3-diode AND gate works.

2. Describe how a diode AND gate works.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT SHEET #3 - OR GATES THROUGH USING DIODES

1. Through the use of a truth table, explain how a 3-diode OR gate works.

2. Describe how a diode OR gate works.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT #4 - DUAL NATURE OF LOGIC GATES

Explain through the use of a truth table, the dual nature of positive and negative logic.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT #5 - MAKING AND PACKAGING A VARIETY OF TTL.

1. Briefly explain how integrated circuits are made.

2. List different methods of packaging IC.

DIGITAL CIRCUITS

UNIT II

LAB SHEET #1 - WIRE AND TEST. THE OPERATION OF AN INTEGRATED CIRCUIT LOGIC INVERTER.

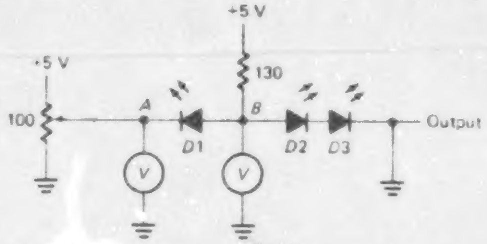
I. Equipment

A. 3-LEDS
B. 1-130 Ω resistor
C. 1-100 Ω potentiometer
D. 1-voltmeter
E. Hookup wire
F. TSVDC power supply
G. Breadboard

II. Procedure

A. Connect the circuit in Figure 1, excluding the voltmeter.

FIGURE 1



The diode inverter causes the output level at point B to be opposite that at point A as shown by the voltmeter readings and the LEDS.

B. Have the instructor check the circuit before applying power to the circuit.

C. Rotate the potentiometer so that ~ 0 volts is applied at point A.

D. Measure the voltage at point

A. Is D1 on or off? ________________

E. Measure the voltage at point

B. Are D2 and D3 on or off? ___________

F. Now rotate the potentiometer all the way in the opposite direction. Is D1 on or off? ________________

LAB SHEET #1

G. Measure the voltage at point B. Are D2 and D3 on or off?___________

H. Complete the truth table in Figure 2 for both cases (D & E and F & G). Let 0 = low volts, 1 = high volts.

FIGURE 2

Input	Output

(NOTE: Show your results to your instructor.)

I. Turn off your power supply.

J. Put your equipment and materials away.

DIGITAL CIRCUITS

UNIT II

LAB SHEET #2 - INTEGRATED CIRCUIT HEX INVERTER

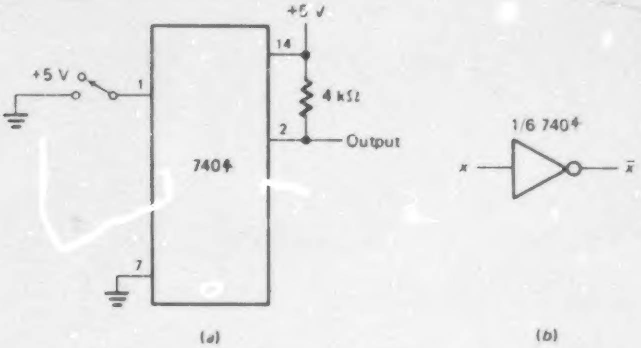
I. Equipment and Materials

A. 1-7404 Hex inverter IC
B. 1-SPDT switch
C. 1-Voltmeter
D. 1-4K resistor
E. Hookup wire
F. +5VDC power supply
G. Breadboard

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1



(a)

(b)

The 7404 hex inverter.

B. Have the instructor check the wiring before applying the +5V.

C. Using the voltmeter measure the output with the SPDT switch opened and closed.

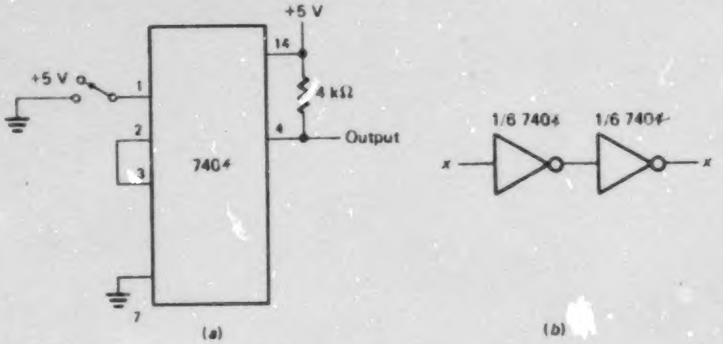
D. Fill in the truth table for Step C.

Input	Output
0V	
+5V	

LAB SHEET #2

E. Now connect the circuit in Figure 2.

FIGURE 2



The 7404 hex inverter.

F. Measure the output with the SPDT switch both open and closed.

G. Fill in the following truth table for step F.

Input	Output
0V	
+5V	

(NOTE: Show your results to the instructor.)

An even number of inverters produces an output that is the same as the input. An odd number of inverters produces a complimentary or opposite result. This type of connecting is called "cascading."

H. Turn off your power supply.

I. Put your equipment and material away.

DIGITAL CIRCUITS

UNIT II

LAB SHEET #3 - WIRE AND TEST THE OPERATION OF LOGIC AND AND OR GATES.

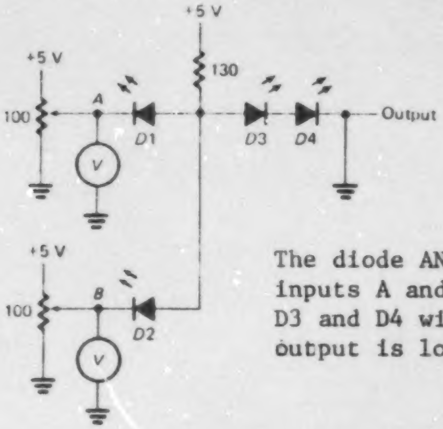
I. Equipment

A. 4-LEDS
B. 2-100Ω potentiometer
C. 1-130 Ω resistor
D. 1-voltmeter
E. +5V power supply
F. Hookup wire
G. Breadboard

II. Procedure

A. Connect the circuit shown in Figure 1. The voltmeter will be used only as a test probe.

FIGURE 1



The diode AND gate has a high output if inputs A and B are both high, so that D3 and D4 will light; otherwise, the output is low.

B. Turn on the +5 power supply.

C. Turn both potentiometers so that OV is applied to points A and B. What voltage readings do you measure at A and B?

______________________________ ______________________

Are D3 and D4 on or off ? D3=___________________________

D4=___________________________

D. Turn potentiometer A so that maximum voltage is applied to point A. What does the voltmeter measure at point A?_________

Are D3 and D4 on or off? D3=_____________________

D4=__________________________

LAB SHEET #3

E. Set the potentiometer so that point A has minimum reading and point B has a maximum reading. What are the voltmeter readings for point A and Point B? A = ____________________

B=__________________________

Are D3 and D4 on or off? D3=________________ D4=______________

F. Set the potentiometers so that both potentiometers have maximum readings. What the voltmeter readings for point A and point B? A=______________________________

B=__________________________

Are D3 and D4 on or off? D3=______________________

D4=________________________

G. Complete the following truth table for the four sets of data obtained in steps C - F.

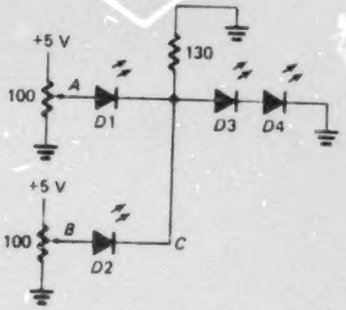
Input	Output
A B	C

(NOTE: Show your results to the instructor.)

H. Turn off your power supply.

I. Connect the circuit shown in Figure 2.

FIGURE 2



The diode OR gate produces a high output whenever any input is high. If either the A input or the B input is high, D3 and D4 will light.

LAB SHEET #3

J. Turn on the power supply.

K. Rotate the potentiometer so that points A and B read minimum voltages. Point A = ______________, Point B = ______________

Are D3 and D4 on or off? D3=________________

D4=________________________

L. Set the potentiometers so that point A reads maximum voltage and point B reads minimum voltage. Point A = ______________

Point B = ______________, Are D3 and D4 on or off?

D3 = ____________________ D4 = ____________________

M. Set the potentiometer so that point A reads minimum voltage and point B reads maximum voltage. Point A = ____________

Point B = ______________. Are D3 and D4 on or off?

D3 = ____________________ D4 = ____________________

N. Set the potentiometers so that both point A and Point B read maximum voltage. Point A = ______________

Point B = ______________. Are D3 and D4 on or off?

D3 = ____________________ D4 = ____________________

O. Complete the following truth table for the four sets of data obtained in steps K - N.

Input		Output
A	B	C

(NOTE: Show your results to the instructor.)

P. Turn off the power supply.

Q. Put away your equipment and materials.

DIGITAL CIRCUITS

UNIT II

LAB SHEET #4 - WIRE AND TEST THE OPERATION OF TTL POSITIVE AND NEGATIVE LOGIC

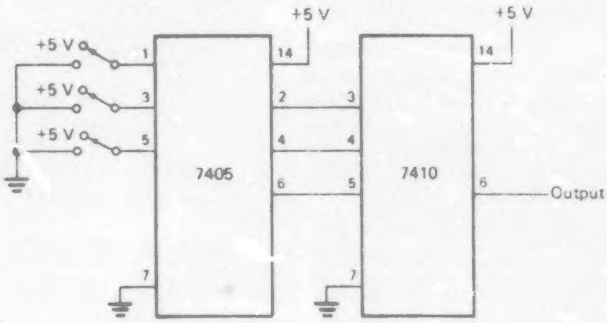
I. Equipment

- A. 1-7405 hex inverter
- B. 1-7410 triple NAND
- C. 3-SPDT switch
- D. 1-voltmeter
- E. 1-+5 volt power supply
- F. Hookup wire
- G. Breadboard

II. Procedure

A. Connect the circuit shown in Figure 1.

FIGURE 1



Changing between positive and negative logic converts functions to a different form. (schematic)

B. Turn on the power supply.

C. Using the procedures in Lab Sheet #3, complete the truth table in Figure 2.

FIGURE 2

Input			Output
A	B	C	D
0V	0V	0V	
0	0	5	
0	5	0	
0	5	5	
5	0	0	
5	0	5	
5	5	0	
5	5	5	

LAB SHEET #4

D. Convert the above truth table to binary 0's and 1's in Figure 3 for positive logic.

FIGURE 3

Input	Output
A B C	D

E. Which Boolean logic symbol does Figure 3 represent?

F. Convert the truth table in Figure 2 to 0's and 1's in Figure 4 for negative logic.

FIGURE 4

Input	Output
A B C	D

G. Which Boolean logic symbol does Figure 4 represent?

H. Since Figure 3 represents a positive AND gate and Figure 4 represents a negative OR (NOR) gate, could a positive OR gate represent a negative AND gate (NAND)? ____________________

____

(NOTE: Show your results to the instructor.)

LAB SHEET #4

I. Turn off the power supply.

J. Put up your equipment and material.

DIGITAL CIRCUITS

UNIT II

LAB SHEET #5 - TTL AND CMOS IN A CIRCUIT

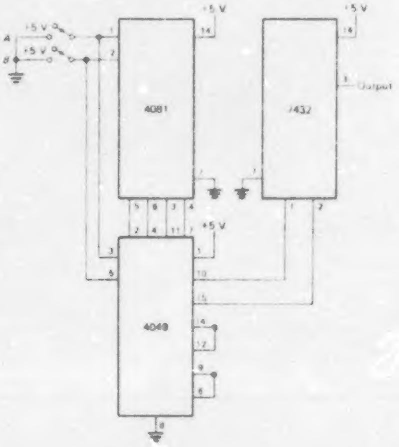
I. Equipment

A. 1-4049 hex inverter
B. 1-4081 quad AND
C. 1-7432 quad DU
D. 1-SPOT switch
E. 1-voltmeter
F. +5 volt power supply
G. Hooking wire
H. Breadboard

II. Procedures

A. Connect the circuit shown in Figure 1. The voltmeter will be used as a test probe.

FIGURE


+5 V
+5 V
A
+5 V
B
+5 V
4081
7432
Output
4049
+5 V
1
2
14
7
5
6
3
4
2
4
11
7
3
5
1
10
15
14
12
9
6
8
14
3
7
1
2

B. Turn on the power.

C. List the circuit and complete the table below.

INPUT		OUTPUT
A	B	
L	L	
L	H	
H	L	
H	L	
H	H	

LAB SHEET #5

D. The outlines in the preceding table shows an example of a ____________ logic circuit. In this circuit, the 4049 is used to ________________ the TTL gate.

(NOTE: Show your results to your instructor.)

E. Turn off your power supply.

F. Put away your equipment.

DIGITAL CIRCUITS

UNIT II

TEST

NAME____SCORE______________

1. Match terms associated with digital circuits to their correct definitions. Write the correct numbers in the blank.

_____a. A gate derived from inverting the output of an AND gate.

_____b. The measure of the speed of operation of a circuit.

_____c. A number that indicates how many gates may be attached to the output of a digital circuit.

_____d. A combination of two or more gates or decision-making elements.

_____e. A circuit whose output is always the opposite of its input.

_____f. The measure of the susceptibility of a logic circuit to noise pulses on inputs and outputs.

_____g. A circuit that has two or more inputs and one output. The output is a binary 1 if any input is a binary 1.

_____h. Positive logic is assigning a binary 1 to high voltage and a binary 0 to low voltage. Negative logic is assigning a binary 1 to low voltage and a binary 0 to high voltage.

_____i. A gate derived from inverting the output of an OR gate.

_____j. A reliability rating--military -55° C to +125° C; commercial 0° C to 70° C.

_____k. When the load appears between the output and the ground of the logic circuit.

_____l. A semiconductor device that combines transistors, diodes, resistors, and capacitors on a silicon chip.

1. Fan out
2. Power dissipation
3. Dual function logic
4. Combinational circuits
5. Inverter circuit
6. Sequential circuits
7. AND gate
8. Temperature range
9. Current sink logic
10. Noise immunity
11. Propagation delay
12. Integrated circuit
13. NOR gate
14. NAND gate
15. Current source logic
16. OR gate

TEST

_____m. The measure of the amount of power consumed by the components in a logic gate or circuit.

_____n. A circuit that has two or more inputs and one output. The output is a binary one only if all inputs are a binary one.

_____o. When the load appears between the output and the supply voltage.

_____p. Interconnected combinational circuits and memory elements to make up counters, registers, and tuners.

2. Match abbreviations or symbols associated with digital circuits to their correct definitions. Write the correct number in the blank.

_____a. Inverse of A.

_____b. A logic circuit that prevents transistor saturation.

_____c. Metal oxide semiconductor circuits.

_____d. The time a pulse takes to go from 10% to 90% of its value.

_____e. Low cost circuit that is used in SSI and MSI elements used for positive logic NAND and negative logic NOR.

_____f. OR operation.

_____g. AND operation.

_____h. The inverter.

_____i. The OR gate.

_____j. The NOR gate.

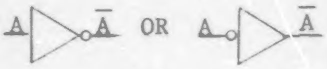
_____k. Medium scale integrated circuits which contain combinational or sequential types.

_____l. The time a pulse takes to go from 90% to 10% of its value.

1. ECL

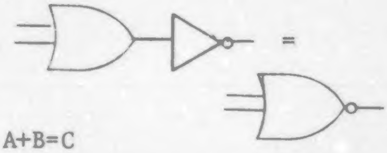
2. $-t_f$

3. LSI

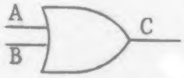
4. 

5. SSI

6. TTL

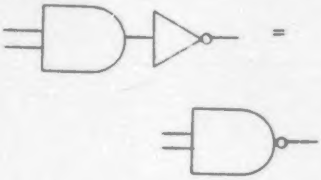
7. 

8. $A+B=C$

9. 

10. $A.B = C$

11. MOS

12. 

TEST

_____m. Large scale integrated circuits which contain whole systems of circuits on one chip.

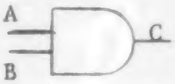
_____n. Small scale integrated circuits which contain NAND, NOR and flip flops.

_____o. The AND gate.

_____p. The NAND gate.

13. $-t_r$

14. MSI

15. 

16. $\overline{A}$

3. Explain how an inverter functions through the use of a truth table.

4. Describe how a simple transistor inverter works.

5. Explain how a three input and gate functions through the use of a truth table.

TEST

6. Describe how a simple diode AND gate works.

7. Explain how a three input OR gate works through the use of a truth table.

8. Describe how a simple diode OR gate works.

9. Explain through the use of a truth table the affect of positive and negative logic.

TEST

10. Explain through the use of a truth table the function of a NAND gate.

11. Explain through the use of a truth table the function of a NOR gate.

12. Explain through the use of logic symbols how AND and OR operations can be performed with NAND and NOR gates.

13. Describe the three basic ways of making integrated circuits.

TEST

14. Name the different ways of packaging integrated circuits.

15. Name four TTL variations.

16. Compare through a table the different types of integrated circuits and their characteristics.

Characteristics	TTL	MOS	ECL
Cost			
Temperature range (°C)			
Supply voltage			
Propagation (NS) gate			
Clock rate			
Fan out			

TEST

17. (NOTE: Test question 17 is lab sheets. They are an important part of this unit. If they have not been completed check with the instructor.)

Demonstrate the ability to

a. Wire and test the operation of integrated circuit logic invertor.

b. Wire and test the operation of logic AND and OR gates.

c. Wire and test the operation of TTL positive and negative logic.

d. Wire and test the operation of both TTL and CMOS devices in one circuit.

18. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

DIGITAL CIRCUITS
UNIT II

ASSIGNMENT SHEET #1 - ANSWERS

1.

INPUT	OUTPUT
V_i	V_o
.1	5
+5	.1

2. With the input voltage at zero volts, the emitter-base is not forward biased so the transistor output will be +5V since the transistor does not conduct.

   With the input voltage at +5V, the transistor is saturated and conducts which leaves the output at approximately 0.1 volts.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT #2 - ANSWERS

1.

INPUTS			OUTPUTS
A	B	C	D
0	0	0	+.7V
0	0	+5V	
0	+5V	0	+.7V
0	+5V	+5V	+.7V
+5V	0	0	
+5V	0	+5V	+.7V
+5V	+5V	0	+.7V
+5V	+5V	+5V	+5V

2. When all inputs are 0 volts, the diodes conduct and the output is approximately zero. When any grouping of inputs have +5 volts applied to them, with the exception of all inputs, the output is still approximately zero. When all inputs have +5 volts applied to them, the diodes will not conduct and the output is +5V.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT SHEET #3 - ANSWERS

1.

A	B	C	D
0	0	0	-.7V
0	0	+5	+4.3V
0	+5	0	+4.3V
0	+5	+5	+4.3V
+5	0	0	+4.3V
+5	0	+5	+4.3V
+5	+5	0	+4.3V
+5	+5	+5	+4.3V

2. When all inputs have 0 volts applied to them, all diode conduct and the output is approximately zero volts. When any one of the inputs is at +5 volts, the diode will conduct causing the output to be about +5V. The remaining diodes at 0 volts have no affect on the circuit.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT #4 - ANSWERS

Input		Output
A	B	C
0V	0V	0V
0V	+5V	0V
+5V	0V	0V
+5V	+5V	+5V

Input		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Input		Output
A	B	C
1	1	1
1	0	1
0	1	1
0	0	0

Instead of having 0 volts = 0 and +5 volts = 1 reverse the assignments.

Assign 0 volts a binary one and +5 volts as binary zero, we arrive at the positive and negative logic. This can be seen in the above table.

DIGITAL CIRCUITS

UNIT II

ASSIGNMENT #5 - ANSWERS

1. a. TO5 can - used to package transistors and a good heat dissipator.

   b. Flat pack - used in high density packaging and not good for heat dissipation.

   c. Dual in-line package - most popular and come in 8-40 per package.

2. Four TTL variations are:

   a. Low power TTL (30-40 nanosecond t_p)

   b. High power TTL (0 nanosecond t_p)

   c. Schottky TTL (3 nanosecond t_p)

   d. Three state TTL (o,1 and open state)

3. TTL

DIGITAL CIRCUITS

UNIT II

TEST ANSWERS

1. a. 14
   b. 11
   c. 1
   d. 4
   e. 5
   f. 10
   g. 16
   h. 3
   i. 13
   j. 8
   k. 9
   l. 12
   m. 2
   n. 7
   o. 15
   p. 6

2. a. 16
   b. 1
   c. 11
   d. 13
   e. 6
   f. 8
   g. 10
   h. 4
   i. 9
   j. 7
   k. 14
   l. 2
   m. 3
   n. 5
   o. 15
   p. 12

3. An inverter has two possible states--on and off--as can be seen through the following truth:

Input	Output
0	1
1	0

4. With the invertor in cut-off, the supply voltage is available to the output and with the inverter forward biased there is approximately zero volts available to the output.

5.

Input			Output
A	B	C	D
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

6. The only time the supply voltage is available to the output is when all inputs are forward biased.

TEST ANSWERS

7.

Inputs			Outputs
E	F	G	H
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

8. The output will be high (5V) when at least one of the inputs is forward biased.

9. Switching from positive logic to negative logic has the affect of changing an OR gate to an AND gate and an AND gate to an OR gate.

Input		Output
A	B	C
0V	0V	0V
0V	+5V	0V
+5V	0V	0V
+5V	+5V	+5V

Input		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Input		Output
A	B	C
1	1	1
1	0	1
0	1	1
0	0	0

10.

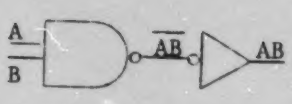
Inputs		Outputs	
A	B	C	$\overline{C}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

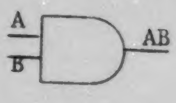
11.

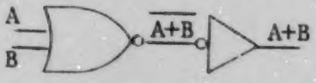
Inputs		Outputs	
A	B	C	$\overline{C}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

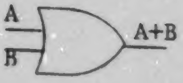
TEST ANSWERS

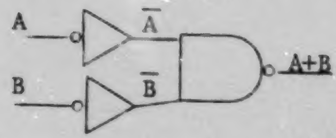
12.

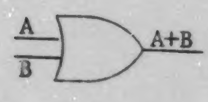

A
B
$\overline{AB}$
AB

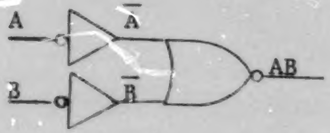


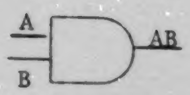

A
B
$\overline{A+B}$
A+B




A
$\overline{A}$
B
$\overline{B}$
A+B




A
$\overline{A}$
B
$\overline{B}$
AB



13. Monolithic - semiconductor material is differred into the bare material to form junctions.

Film - depositing on a ceramic basic material to form resistors, capacitors, and indicators.

Hybrid - a combination of monolithic and film methods.

14. TOS can
Flat pack
Dual in-line package

15. Low power TTL
High power TTL
Schottry TTL
Three state TTL

16.

Characteristics	TTL	MOS	ECL
Cost	low	high	high
Temp Range (^{o}C)	-55 to +125	-55 to +125	-55+125
Supply voltage	+5	+5 to -27	-5.2
Propagation (ns) gate	3-12	50-200	1-2
Clock rate	15-120	2-10	200-1000
Fan out	10	20	25

17. Performance skills evaluated by the instructor.

DIGITAL ELECTRONICS

UNIT III

BOOLEAN ALGEBRA

BOOLEAN ALGEBRA

UNIT III

OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to construct Boolean expression, truth tables and circuits. The student should also be able to minimize logic circuits through the use of Boolean algebra. This knowledge will be shown by completing assignment sheets, lab sheets, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with Boolean algebra with their correct definition.
2. Identify symbols associated with Boolean algebra.
3. Construct Boolean expressions from digital logic circuits.
4. Design digital logic circuits from Boolean expressions.
5. Construct a truth table from a given Boolean expression.
6. Write a Boolean expression from a truth table.
7. Write minimum Boolean expression utilizing rules of Boolean algebra.
8. Demonstrate the ability to
    - A. Wire and operate NAND and NOR gates.
    - B. Minimize a circuit through Boolean algebra.
    - C. Wire and test a multiplexer.

BOOLEAN ALGEBRA

UNIT III

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.
  B. Provide students with information, assignment and lab sheets.
  C. Make transparencies.
  D. Discuss unit and specific objective.
  E. Discuss information, assignment, and lab sheets.
  F. Demonstrate the writing of Boolean expression from digital circuits.
  G. Demonstrate the conversion of Boolean expression into digital circuits.
  H. Demonstrate how Boolean algebra can be used to minimize a digital ciruits.
  I. Assist students in connection and troubleshooting gates.
  J. Assist students in minimizing digital circuits.
  K. Give test.

II. Student

  A. Read objective sheets.
  B. Study information sheets.
  C. Complete assignment sheets.
  D. Complete lab sheets.
  E. Take test.

BOOLEAN ALGEBRA
UNIT III
INSTRUCTIONAL MATERIAL

I. Included in this unit:

   A. Objective sheets.

   B. Information sheets.

   C. Assignment sheets.

   D. Lab sheets.

   E. Test.

   F. Answers to assignment sheets.

   G. Answers to test.

II. References

   A. Pasahow, Edward L., Learning Digital Electronics Through Experiments, New York, New York, McGraw-Hill, 1982.

   B. Pasahow, Edward I., Digital Integrated Circuits, New York New York, McGraw-Hill Boox Co. 1979.

   C. Leach, Donald P., Experiments in Digital Principle, New York, New York, McGraw-Hill Book Co. 1981.

   D. Miller, Michael A., Digital Computers Electronics, New York, New York, McGraw-Hill Book Co. 1983.

III. Other References.

   Digital Techniques, Vol. I and II. Benton Harbor, Michigan, Heath Company, 1983.

BOOLEAN ALGEBRA

UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Boolean algebra - a systematic method of designing integrated circuits.

B. Minimize a function - selecting integrated circuits in such a way to achieve an efficient design.

C. Boolean expression - an algebraic equation that expresses the output of a logic circuit.

D. Sum-of-Products - $G=(A \cdot B)+(C \cdot D)+E \cdot F)$ The sum-of-products circuit uses an OR gate output. This circuit is most common.

E. Product-of-Sums - $G=(A+B) \cdot (C+D) \cdot (E+F)$ The product-of-sums circuit uses an AND gate output.

F. Truth table - a chart that lists all possible input and output signal combinations. Logic circuits can be developed from truth tables. The inverse is also true.

G. Laws of Intersection - applies to AND gates

a. $A \cdot 1 = A$

b. $A \cdot 0 = 0$

Example:

Input		Output
A	B	C
0	0	0
0	1	0
0	0	0
1	1	1

Line 1 and 3 prove b.
Line 2 and 4, prove a.

H. Laws of Union - applies to OR gates

a. $A + 1 = 1$

b. $A + 0 = A$

Example:

Input		Output
A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

Line 2 and 4 prove a.
Line 1 and 3 prove b.

INFORMATION SHEET

I. Laws of Tautology - applies to both AND and OR gates.
Example:

$A \cdot A = A$
$A + A = A$

Input		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

J. Law of Complements - $A \cdot \overline{A} = 0$

$A + \overline{A} = 1$

K. Law of the Double Negative - $A = \overline{\overline{A}}$

L. Law of Commutation - $A \cdot B = B \cdot A$

$A + B = B + A$

M. Law of Association - $(AB)C = A(BC) = ABC$

$A+(B+C) = (A+B) + C = A+B+C$

N. Laws of Distribution - $(A+B)(A+C) = A+BC$

O. Laws of Absorption - $A(A+B) = A$

$A(\overline{A}+B) = AB$

$AB+\overline{B} = A+\overline{B}$

$A\overline{B}+B = A+B$

P. DeMorgan's Theorem - $\overline{AB} = \overline{A} + \overline{B}$

$\overline{A+B} = \overline{AB}$

II. Symbols

A. $C = A \cdot B$ - the dot indicates the AND function between A and B to give C. Also, C = AB. "." = product as well.

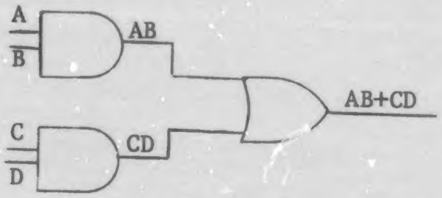
B. C = A+B - the plus sign indicates that A and B are ORed to give C. "+" = sum as well.

C. 2" = x - " x " is the possible number of combinations that "n" inputs can have.

INFORMATION SHEET

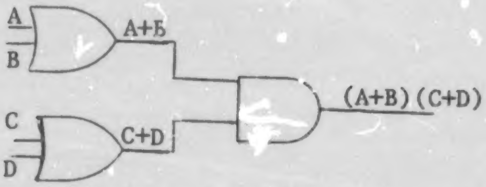
III. Boolean expressions from logic circuits. Start at the inputs and write the expression for each gate from right to left. Examples:

A. Sum-of-Products


A
B
AB
C
D
CD
AB+CD

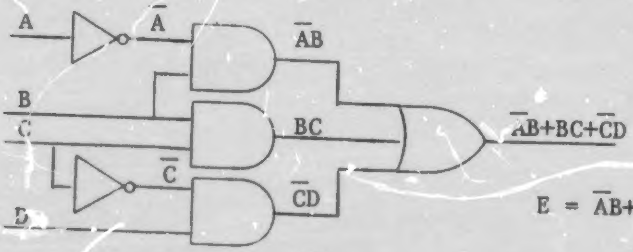
$E = AB+CD$

B. Product-of-Sums


A
B
A+B
C
D
C+D
(A+B)(C+D)

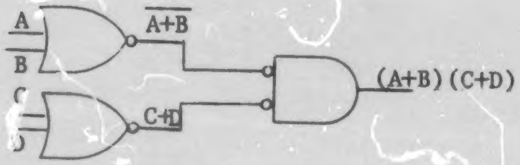
$E = (A+B)(C+D)$

C. More logic levels


A
$\overline{A}$
$\overline{A}B$
B
C
BC
$\overline{C}$
D
$\overline{C}D$
$\overline{A}B+BC+\overline{C}D$

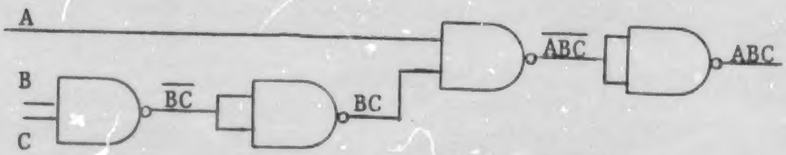
$E = \overline{A}B+BC+\overline{C}D$

D.


A
B
$\overline{A+B}$
C
D
$\overline{C+D}$
(A+B)(C+D)

$E = (A+B)(C+D)$

E.

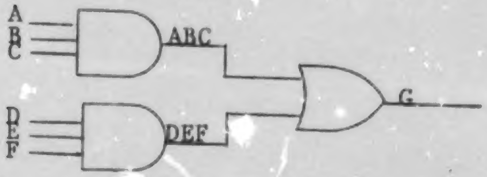

A
B
C
$\overline{BC}$
BC
$\overline{ABC}$
ABC

$D = ABC$

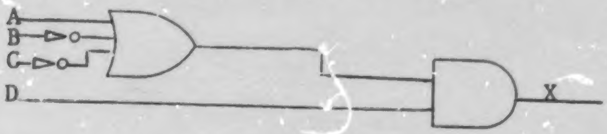
INFORMATION SHEET

IV. Designing logic circuits from Boolean expression. First determines if the expression is a sum-of-products or a product-of-sums. Then work backwards from the output to the input or from right to left. Examples:

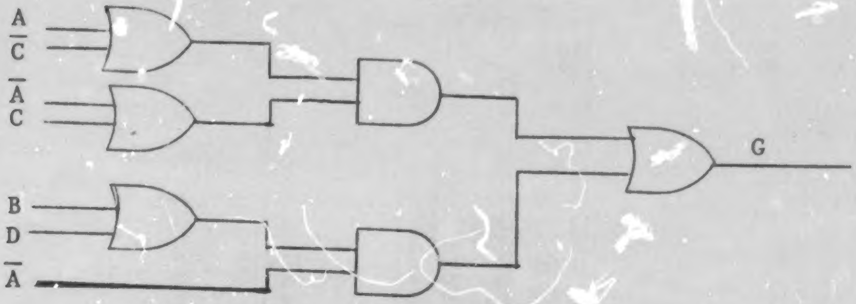
A. G = ABC + DEF (sum-of-products)



B. $X = (A + \overline{B} + \overline{C})\,D$ (product-of-sums)



C. $G = (A + \overline{C})\,(\overline{A} + C) + (B + \overline{D})\,\overline{A}$ (sum-of-products)



(NOTE: The sum-of-products is the most used logic.)

V. Truth tables are used to prove Boolean expressions. Examples:

A. $(A+B+C)(A+\overline{B}+C) = A+C$ (n = 3 therefore: $2^n = 2^3 = 8$ combinations)

1	2	3	4	5	6
ABC	$\overline{B}$	A+B+C	$A+\overline{B}+C$	$(A+B+C)(A+\overline{B}+C)$	A+C
000	1	0	1	0	0
001	1	1	1	1	1
010	0	1	0	0	0
011	0	1	1	1	1
100	1	1	1	1	1
101	1	1	1	1	1
110	0	1	1	1	1
111	0	1	1	1	1

INFORMATION SHEET

As can be seen from the truth table, column 5 has the same result as column 6. NOTE: This also tells us that the expression on the left which represents a product-of-sums logic circuit could be replaced with one OR gate. A money saving reason for learning how to use Boolean algebra and minimizing expressions to cut down on devices.

VI. Writing Boolean expressions from truth tables which were deduced from circuit requirements. Steps in designing a circuit

A. Determine the inputs.

B. Determine the outputs for each set of inputs.

C. Put step B into a truth table.

D. For each binary 1 output state write a product from the inputs.

E. Combine the products as a sum-of-products.

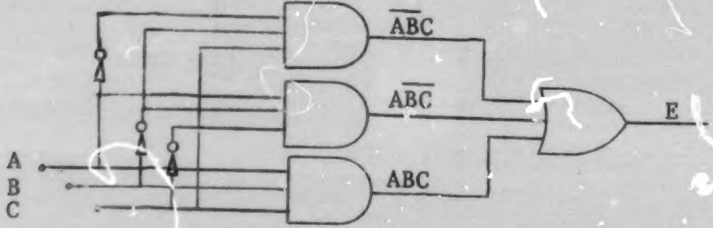
F. From the resulting expression build the necessary circuit.

Example: Write a logic circuit for the given truth table.

A B C	D
0 0 0	0
0 0 1	1
0 1 0	0
0 1 1	0
1 0 0	1
1 0 1	0
1 1 0	0
1 1 1	1

Step A. $n = 3$; $2^3 = 8$ combinations
Step B. Shown in the truth table
Step C. Already done
Step D. For a binary 0 put the complement state
Line 2 $\overline{AB}C$
Line 5 $A\overline{BC}$
Line 8 ABC

Step E. $E = \overline{AB}C+A\overline{BC}+ABC$
Step F.



INFORMATION SHEET

VII. Minimizing Boolean expressions utilizing Boolean algebra.

Examples:

A. Show: $A+B+\overline{B} = 1$

$A+1 = 1$ Law of Complements
$1 = 1$ Laws of Union

B. Show: $AB\overline{B}C = 0$

$0 = 0$ ($B\overline{B} = 0$; Law of Complements)

C. Show: $A+B+A = A+B$

$A+B = A+B$ ($A+A = A$ Law of Tantology)

D. Show: $A(A+B) = A$

$AA+AB =$ Law of Distribution
$A+AB =$ Law of Tantology
$A(1+B) =$ Factor
$A(2) =$ Laws of Union
$A = A$ Law of Intersection

E. Show: $\overline{AB} = \overline{A+B}$

$\overline{A}+\overline{B} =$ DeMorgan's Theorem
$A+B =$ Complement each term
$A+B =$ Law of Complement

$\overline{A+B} = \overline{A}+\overline{B}$ Complement both terms

F. Show: $A\overline{B}\,\overline{C} + AB\overline{C} + A\overline{B}C + \overline{A}B\overline{C} = A\overline{B} + B\overline{C}$

$A\overline{BC}+A\overline{B}C+AB\overline{C}+\overline{A}B\overline{C} =$ Regrouping

$A\overline{B}(\overline{C}+C)+(A+\overline{A})B\overline{C} =$ Factoring

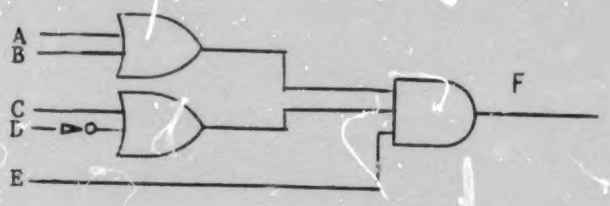
$A\overline{B}+B\overline{C} = A\overline{B}+B\overline{C} =$ Law of Complement

BOOLEAN ALGEBRA

UNIT III

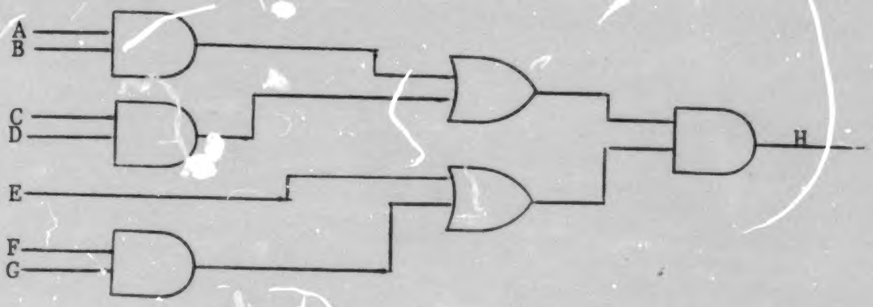
ASSIGNMENT SHEET #1 - CONSTRUCTING BOOLEAN EXPRESSIONS FROM DIGITAL LOGIC CIRCUITS

1. Write a Boolean expression for the following circuit



F = ______________________________

2. Write a Boolean expression for the following circuit.



H = ______________________________

BOOLEAN ALGEBRA

UNIT III

ASSIGNMENT SHEET #2 - DESIGNING DIGITAL LOGIC CIRCUITS FROM BOOLEAN EXPRESSION.

1. Design a logic circuit from the following expression:

$$F = (A+B)(C+\overline{D})E$$

2. Design a logic circuit from the following expression.

$$E = \overline{A}B+CD+\overline{BC}D$$

BOOLEAN ALGEBRA

UNIT III

ASSIGNMENT SHEET #3 - CONSTRUCT TRUTH TABLES FROM GIVEN BOOLEAN EXPRESSION.

1. Construct a truth table from the given expression.

$$D = (A+B)(B+C)$$

2. Construct a truth table from the given expression.

$$D = \overline{A}\overline{BC}+\overline{A}BC+A\overline{BC}+AB\overline{C}$$

BOOLEAN ALGEBRA

UNIT III

ASSIGNMENT SHEET #4 - WRITING BOOLEAN EXPRESSIONS FROM A TRUTH TABLE.

1. Write an expression from the following truth table.

Inputs		Output
A	B	C
0	0	0
0	1	1
1	0	1
1	1	0

C = ________________________________

2. Write an expression from the following truth table.

Inputs			Output
A	B	C	D
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

D = ________________________________

BOOLEAN ALGEBRA

UNIT III

ASSIGNMENT # 5 - MINIMIZING BOOLEAN EXPRESSIONS UTILIZING RULES OF BOOLEAN ALGEBRA.

1. Show the following expression is true by using Boolean rules of algebra.

$$(A+B+\overline{C})\ (\overline{A}+B+\overline{C}) = B+\overline{C}$$

2. Show the following expression is true by using DeMorgan's theorem and the Boolean rules of algebra.

$$\overline{\overline{A}B+A\overline{B}} = AB+\overline{AB}$$

BOOLEAN ALGEBRA

UNIT III

LAB SHEET #1 - WIRE AND OPERATE NAND AND NOR GATES

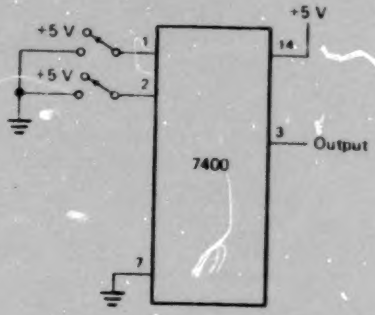
I. Equipment

- A. 1 - 7400 NAND gate
- B. 1 - 7402 NOR gate
- C. 2 - SPDT switch
- D. 1 - Voltmeter
- E. +5V Power supply
- F. Breadboard
- G. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1

FIGURE 1



B. Turn on the power supply.

C. Complete the truth table in Figure 2

FIGURE 2

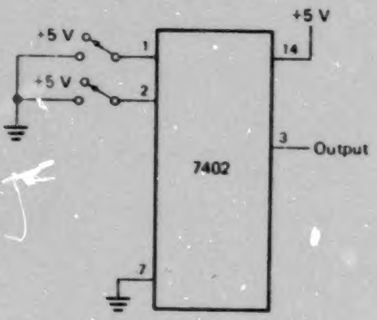
A	B	Output
0V	0V	
0	5	
5	0	
5	5	

(NOTE: ALL outputs should be high except when A and B are high.)

LAB SHEET #1

D. Connect the circuit in Figure 3

FIGURE 3



E. Turn on the power supply.

F. Complete the truth table in Figure 4.

FIGURE 4

A	B	Output
OV	OV	
0	5	
5	0	
5	5	

(NOTE: ALL outputs should be low except when A and B are low.)

G. Turn off the power supply.

(NOTE: Show the result to the instructor.)

H. Put up your equipment.

BOOLEAN ALGEBRA

UNIT III

LAB SHEET #2 - MINIMIZE A CIRCUIT THROUGH BOOLEAN ALGEBRA

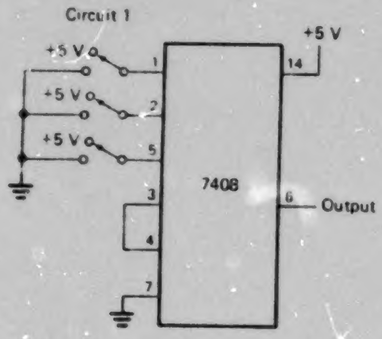
I. Equipment

A. 1 - 7408 AND
B. 1 - 7411 AND
C. 1 - 9432 OR
D. 3 - SPDT switch
E. 1 - Voltmeter
F. +5V Power supply
G. Breadboard
H. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1

FIGURE 1


Circuit 1
+5 V
+5 V
+5 V
1
2
5
3
4
7
14
+5 V
7408
6
Output

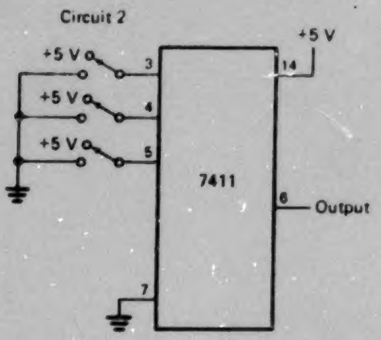
B. Complete the truth table in Table 1

TABLE 1

A	B	C	Output
OV	OV	OV	
0	0	5	
0	5	0	
0	5	5	
5	0	0	
5	0	5	
5	5	0	
5	5	5	

LAB SHEET #2

C. Now connect the circuit in Figure 2.


Circuit 2
+5 V
+5 V
+5 V
+5 V
3
4
5
14
7411
6
Output
7

D. Complete the truth table in Table 2.

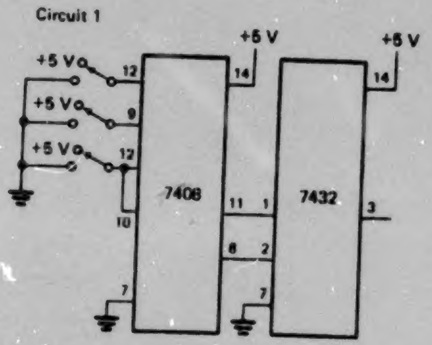
TABLE 2

A	B	C	Output
OV	OV	OV	
0	0	5	
0	5	0	
0	5	5	
5	0	0	
5	[illegible]	5	
5	5	[illegible]	
5	5	5	

(NOTE: Show your results to the instructor. By regrouping you were able to eliminate one gate (AB)C = ABC.

E. Now connect the circuit in Figure 3.

FIGURE 3


Circuit 1
+5 V
+5 V
+5 V
+5 V
+5 V
12
9
12
10
14
7408
7
11
8
1
2
7432
14
3
7

LAB SHEET #2

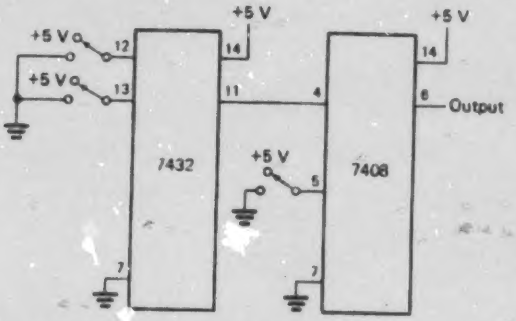
F. Complete the truth table in Table 3

TABLE 3

A	B	C	Output
OV	OV	OV	
0	0	5	
0	5	0	
0	5	5	
5	0	0	
5	0	5	
5	5	0	
5	5	5	

G. Connect the circuit in Figure 4

Figure 4


+5 V
+5 V
12
+5 V
13
14
11
7432
7
+5 V
4
+5 V
14
6
Output
5
7408
7

H. Complete the truth table in Table 4

TABLE 4

A	B	C	Output
OV	OV	OV	
0	0	5	
0	5	0	
0	5	5	
5	0	0	
5	0	5	
5	5	0	
5	5	5	

(NOTE: Show your results to the instructor. You saved one gate and obtained the same results AB+AC = A(B+C)

LAB SHEET #2

I. Turn off the power supply.

J. Put up your equipment.

BOOLEAN ALGEBRA

UNIT III

LAB SHEET #3 - WIRE AND TEST A MULTIPLEXER

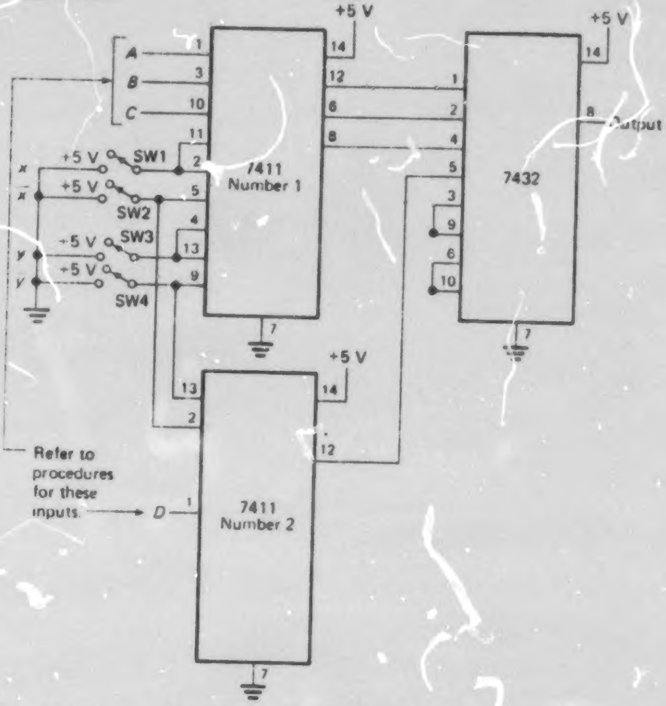
I. Equipment and material

- A. 2 - 7411 AND gates
- B. 1 - 7432 OR gate
- C. 4 - SPDT switches
- D. 1 - Voltmeter
- E. +5 Volt power supply
- F. Breadboard
- G. Hook-up wire

II. Procedures

A. Connect the circuit in Figure 1

FIGURE 1


+5 V
+5 V
A
B
C
1
3
10
11
2
5
4
13
9
14
12
6
8
7411
Number 1
7
+5 V SW1
+5 V
SW2
+5 V SW3
+5 V
SW4
x
$\bar{x}$
y
$\bar{y}$
1
2
4
5
3
9
6
10
14
8
Output
7432
7
+5 V
13
2
14
12
Refer to procedures for these inputs
D
1
7411
Number 2
7

B. To test the circuit connect A, B, C and D to +5V.

C. Test the output with the voltmeter.

D. The output should remain high for:

SWITCH			
1	2	3	4
closed	open	closed	open
closed	open	open	closed
open	closed	closed	open
open	closed	open	closed

NOTE: If the output goes low, check all wiring and repeat Step D.

LAB SHEET #3

E. Ground A with B, C, D connected to 5V. Close switches 1 and 3, open 2 and 4. The output level is high/low? ____________________

F. Ground B with A, C, D connecting to 5V. Close switches 1 and 4, open 2 and 3. The output level is high/low? ____________________

G. Ground C with A, B, D connected to 5V. Close switches 2 and 3, open 1 and 4. The output level is high/low? ____________________

H. Ground D with A, B, C connected to 5V. Close switches 2 and 4, open 1 and 3. The output level is high/low? ____________________

I. As was seen all outputs for steps E - H were low suggesting that a multiplexer is a device that selects outputs by the address that is placed on the switches.

J. These results can be summarized as:

Outputs	Closed Switches
A	1 and 3
B	2 and 3
C	1 and 4
D	2 and 4

(NOTE: Show your results to the instructor.)

K. Turn off the power supply.

L. Put up your equipment.

BOOLEAN ALGEBRA

UNIT III

TEST

NAME____SCORE_______________

1. Match terms aysociated with Boolean algebra with their correct definitions.

______a. Laws applying to AND gates.

______b. Laws applying to both AND and OR gates.

______c. A systematic method of designing integrated circuits.

______d. Uses an OR gate output.

______e. Laws applying to OR gates.

______f. A chart that lists all possible input and output signal combinations.

______g. An algebraic equation that expresses the output of a logic circuit.

______h. Selecting integrated circuits in such a way to achieve an efficient design.

______i. Uses an AND gate output.

______j. Law of Complements

______k. DeMorgan's Theorem

______l. Laws of Distribution

______m. Law of Commutation

______n. Laws of Absorption

______o. Law of Association

______p. Law of the Double Negative

1. $\overline{AB} = \overline{A} + \overline{B}$

   $\overline{A+B} = \overline{AB}$
2. Laws of Tantology
3. Truth table
4. Minimize a function
5. Product-of-sums circuit
6. Laws of Union
7. Boolean expression
8. $A \bullet \overline{A} = 0$

   $A + \overline{A} = 1$
9. Laws of Intersection
10. $(AB)C = A(BC)=ABC$

    $A+(B+C)=(A+B)+C=A+B+C$
11. $A(A+B)=A$

    $A\ (\overline{A}+B)=AB$

    $AB+\overline{B}=A+\overline{B}$

    $A\overline{B}+B=A+B$
12. Boolean algebra
13. $A=\overline{\overline{A}}$
14. $A{\bullet}B=B{\bullet}A$

    $A+B=B+A$
15. $(A+B)(A+C)=A+BC$
16. Sum-of-Products

TEST

2. Identify symbols associated with Boolean algebra. Write the correct answer in the blanks.

a. A • B ____

____

____

____

b. A+B ____

____

____

____

c. $2^n = X$ ____

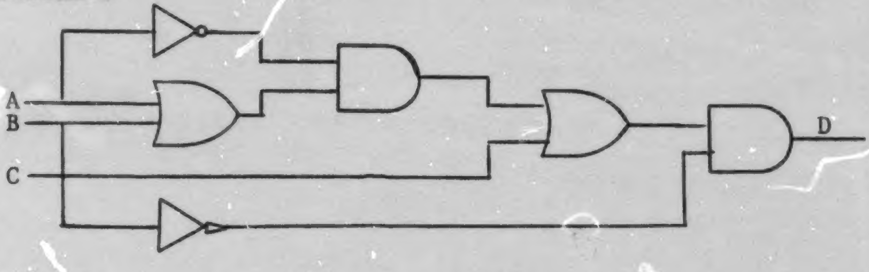
____

____

____

3. From the logic circuit in Figure 1, write a Boolean expression.

FIGURE 1



D = ____

TEST

4. Design a digital logic circuit from the Boolean expression in Figure 2.

FIGURE 2

$$R = ADD \cdot CLR + SUB \cdot \overline{INV} + MPY \cdot ADD \cdot SUB$$

5. Construct a truth table from the expression in Figure 3.

FIGURE 3

$$D = AB + \overline{B}C$$

6. Derive a Boolean expression from the truth table in Figure 4.

FIGURE 4

Input			Output
A	B	C	D
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

D = ______________________________

TEST

7. Minimize the Boolean expression in Figure 5 using Boolean algebra.

FIGURE 5

$$D = \overline{B}(\overline{A}(A+B)+C)$$

(NOTE: Test question 8 pertains to lab sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

8. Demonstrate the ability to

   A. Wire and operate NAND and NOR gates

   B. Minimize a circuit through Boolean algebra

   C. Wire and test a multiplexes

BOOLEAN ALGEBRA

UNIT III

ASSIGNMENT SHEET #1 - ANSWERS

1. $(A+B)(C+\overline{D})E = F$
2. $(AB+CD)(E+FG) = H$

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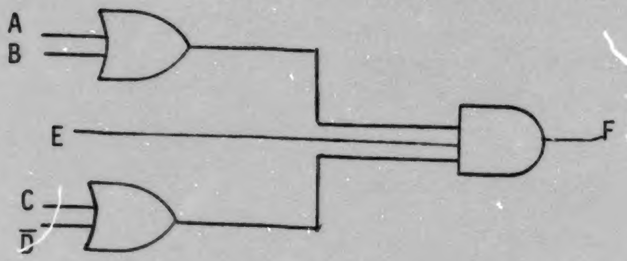
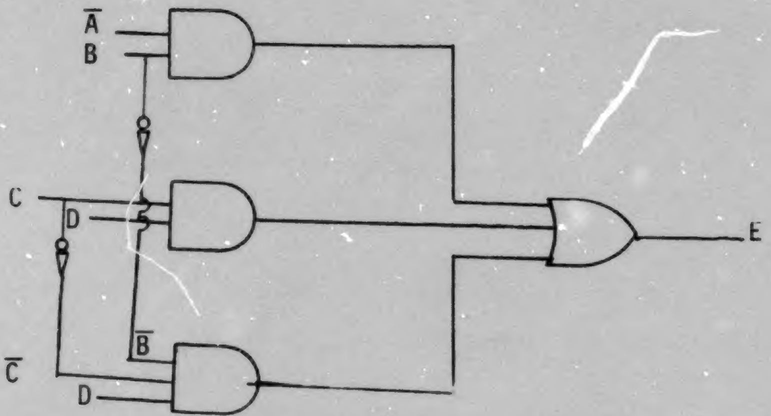
UNIT III

ASSIGNMENT SHEET #2 - ANSWERS

1.


A
B
E
F
C
$\overline{D}$

2.


$\overline{A}$
B
C
D
E
$\overline{B}$
$\overline{C}$
D

BOOLEAN ALGEBRA

UNIT III

ASSIGNMENT SHEET #3 - ANSWER SHEET

1.

A	B	C	A+B	B+C	(A+B)(B+C)
0	0	0	0	0	0
0	0	1	1	1	1
0	1	0	1	1	1
0	1	1	1	1	1
1	0	0	1	0	0
1	0	1	1	1	1
1	1	0	1	1	1
1	1	1	1	1	1

2.

A	B	C	$\overline{A}$	$\overline{B}$	$\overline{C}$	$\overline{A}\overline{B}\overline{C}$	$\overline{A}BC$	$A\overline{B}\overline{C}$	$AB\overline{C}$
0	0	0	1	1	1	1	0	0	0
0	0	1	1	1	0	0	0	0	0
0	1	0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	1	0	0
1	0	0	0	1	1	0	0	1	0
1	0	1	0	1	0	0	0	0	0
1	1	0	0	0	1	0	0	0	1
1	1	1	0	0	0	0	0	0	0

$\overline{A}\overline{B}\overline{C} + \overline{A}BC + A\overline{B}\overline{C} + AB\overline{C}$
1
0
0
1
1
0
1
0

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UNIT III

ASSIGNMENT SHEET #4 - ANSWER SHEET

1. $\overline{A}B + A\overline{B} = C$
2. $\overline{ABC} + \overline{A}BC + A\overline{BC} + AB\overline{C}$

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UNIT III

ASSIGNMENT SHEET #5 - ANSWER SHEET

1. $(A+B+\bar{C})(\bar{A}+B+\bar{C}) = B+\bar{C}$

(expanding)

$\overset{0}{\cancel{A\bar{A}}}+AB+A\bar{C}+B\bar{A}+\overset{B}{\cancel{BB}}+B\bar{C}+\bar{C}\bar{A}+\bar{C}B+\overset{\bar{C}}{\cancel{\bar{C}\bar{C}}} =$

Tautology and complements

$AB+A\bar{C}+B\bar{A}+B+B\bar{C}+C\bar{A}+\bar{C}B+\bar{C} =$

Commutation

$A\bar{C}+B\bar{C}+\bar{A}\bar{C}+AB+\bar{A}B+B =$

Factor

$\bar{C}(A+B+\bar{A}+1)+B(A+\bar{A}+1) =$

Union

$\bar{C}(1)+B(1) =$

Intersection

$\bar{C}+B = B+\bar{C}$

2. ____________________

$\bar{A}B+A\bar{B} =$

Demorgan

$(\overline{\bar{A}\ B})(\overline{A\ \bar{B}}) =$

Complement

$(A\bar{B})(\bar{A}B) =$

Commutative

$(AB)(\overline{AB}) =$

Demorgan

$\overline{AB}+AB$

BOOLEAN ALGEBRA

UNIT III

TEST ANSWERS

1. a. 9
   b. 2
   c. 12
   d. 16
   e. 6
   f. 3
   g. 7
   h. 4
   i. 5
   j. 8
   k. 1
   l. 15
   m. 14
   n. 11
   o. 10
   p. 13

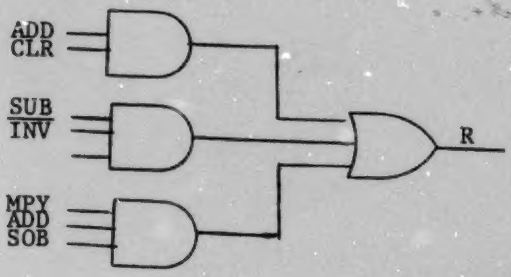
2. a. The dot indicates the AND function between A and B. "." = product

   b. The plus sign indicates the OR function between A and B. "+"

   c. "x" is the possible number of combinations that "n" inputs can have.

3. $D = \overline{A}(A+B)+C$

4.



5.

A	B	C	$\overline{B}$	AB	$\overline{B}C$	$AB+\overline{B}C$
0	0	0	1	0	0	0
0	0	1	1	0	1	1
0	1	0	0	0	0	0
0	1	1	0	0	0	0
1	0	0	1	0	0	0
1	0	1	1	0	1	1
1	1	0	0	1	0	1
1	1	1	0	1	0	1

6. $D = \overline{AB}C+A\overline{B}C+AB\overline{C}+ABC$

7. $D = \overline{B}C$

8. Performance skills evaluated to satisfaction of instructor.

DIGITAL ELECTRONICS

UNIT IV

FLIP-FLOPS

FLIP-FLOPS

UNIT IV

OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to construct and test the latch, D, and J - K flip-flops. This knowledge will be shown by completing the lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with flip-flops to their definition.
2. Describe how a latch type flip-flop works.
3. Describe how a D type flip-flop works.
4. Describe how a J - K type flip-flop works.
5. Demonstrate the ability to
   - A. Construct a latch flip-flop.
   - B. Construct a D flip-flop.
   - C. Construct a J - K flip-flop.

FLIP FLOPS

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with information sheets and lab sheets.

  C. Make transparencies.

  D. Discuss unit and specific objective.

  E. Discuss information and lab sheets.

  F. Demonstrate how various flip-flop work.

  G. Assist students in constructing flip-flops.

  H. Give test.

II. Student

  A. Read objective sheet.

  B. Study assignment sheets.

  C. Complete lab sheets.

  D. Take test.

FLIP FLOPS

UNIT IV

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Information sheets.

  C. Lab sheets.

  D. Test.

  E. Answers to test.

II. References

  A. Pasahow, Edward I., Learning Digital Electronics Through Experiments, New York, New York, McGraw-Hill, 1982.

  B. Pasahow, Edward I., Digital Integrated Circuits, New YOrk New York McGraw-Hill Book Co. 1979.

  C. Leach, Donald P., Experiments in Digital Principle, New York, New York, McGraw-Hill Book Co., 1981

  D. Miller, Michael A., Digital Computers Electronics, New York, New York, McGraw-Hill Book Co., 1983.

FLIP-FLOPS

UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Flip-flop - a logic circuit whose function is memory.

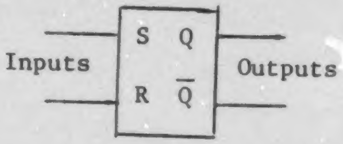
B. Latch - simplest form of binary storage.

C. D type - another form of flip-flop where the output follows the D input when the T line is high.

D. J-K type - this flip-flop has functions of the other flip-flops plus it can store two bites although one bit is responsible for the state of the flip-flop.

II. The latch type flip-flop symbol is shown in Figure 1.

FIGURE 1



A. Inputs

A - when this line goes high the flip-flop is set and is storing a binary 1.

R - when this line goes high the flip-flop is storing a binary 0.

B. Outputs

Q - when the flip-flop is set this line is high.

$\overline{Q}$ - when the flip-flop is reset this line is high.

C. The truth table for the latch type flip-flop:

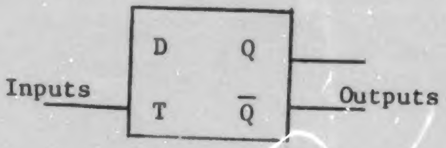
Inputs		Outputs	
S	R	Q	$\overline{Q}$
0	0	Q_o	$\overline{Q}_o$
0	1	0	1
1	0	1	0
1	1	ambiguous	

(NOTE: With both S and R lines high, the latch is in an undetermined state. With both S and R lines low the Q and $\overline{Q}$ lines are in the state they were previously set, just opposite from each other.)

D. Used to eliminate contact bounce in switching.

III. The D type flip-flop is shown in Figure 2.

FIGURE 2



A. Inputs

D - A high on this line will set the flip-flop if the T line is high.

T - this line enables the flip-flop when there is a high on it.

B. Output

Q - this line is high when the flip-flop is set.

$\overline{Q}$ - this line will be the opposite of the Q line.

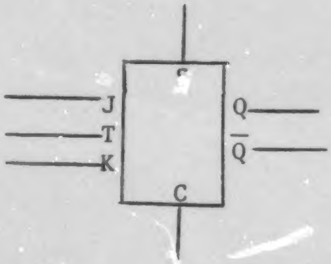
C. A truth table for the D type flip-flop:

Inputs		Outputs	
D	T	Q	$\overline{Q}$
0	0	Q_o	$\overline{Q}_o$
0	1	0	1
1	0	Q_o	$\overline{Q}_o$
1	1	1	0

(NOTE: When the T line is low the state of the flip-flop will be in its previously set state.)

IV. The symbol for a J-K flip-flop is shown in Figure 3.

FIGURE 3



INFORMATION SHEET

A. Inputs

J - this line is similar to a set line but is under control of the T line.

K - this line is similar to a reset line but is under the control of the T line.

T - when this line is low both J and K lines are ineffective.

S - when this line is low the flip-flop is set.

C - when this line is low the flip-flop is reset.

B. Outputs

Q - this line will be high when the flip-flop is set.

$\overline{Q}$ - this line will be high when the Q line is low.

C. A truth table for the J-K flip-flop:

Inputs					Outputs	
S	C	J	K	T	Q	$\overline{Q}$
L	H	X	X	X	1	0
H	L	X	X	X	0	1
L	L	X	X	X	ambiguous	
H	H	0	0	H	Q_o	$\overline{Q}_o$
H	H	0	1	H	0	1
H	H	1	0	H	1	0
H	H	1	1	H	toggling	

(NOTE: With one of the S or C lines low the J, K and T lines are ignored. With S and C lines H and the T line low the state of the flip-flop remains unchanged.)

D. Through the "toggling" function the J-K flip-flop becomes a frequency divider.

FLIP-FLOPS

UNIT IV

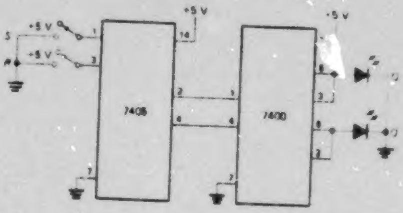
LAB SHEET #1 - CONSTRUCT A LATCH FLIP-FLOP

I. Equipment

- A. 1 - 7400 NAND gate
- B. 1 - 7405 inverter
- C. 2 - SPDT switch
- D. 2 - LEDS
- E. +5V Power supply
- F. Breadboard
- G. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.



B. Turn on the power supply.

C. Apply a high to the S line and a low to the R line. What are the states of the outputs? Q = ______________________

$\overline{Q}$ = ______________________

(NOTE: Set state: Q=high, $\overline{Q}$=low)

D. Without changing anything apply a low to both R and S line (open the switches). What are the states of the outputs?

Q=______________________ $\overline{Q}$=______________________

(NOTE: there is no change in the outputs. One LED is on while the other is off. (Q_o and $\overline{Q}_o$). The LATCH has a memory.

E. Now apply a high to the R line and a low to the S line. What are the output states? Q=________________ $\overline{Q}$=________________

(NOTE: The latch has changed state.)

LAB SHEET #1

F. Again apply a low to both R and S lines. There should be no change.

G. This time apply a high to both R and S lines. What state are the outputs in this time? Q=____________________________

$\overline{Q}$= ________________________________.

(NOTE: This state is called a don't know state, ambiguous or undetermined state. It all depends on the previous state setting. Try different combinations of high and lows ending with step G to verify this.)

H. Complete the truth table for the latch.

Input		Output	
R	S	Q	$\overline{Q}$
0	0		
0	1		
1	0		
1	1		

(NOTE: Have the instructor inspect your results.)

I. Turn off the power supply.

J. Put up your equipment.

FLIP-FLOPS

UNIT IV

LAB SHEET # 2 - CONSTRUCT A "D" FLIP-FLOP

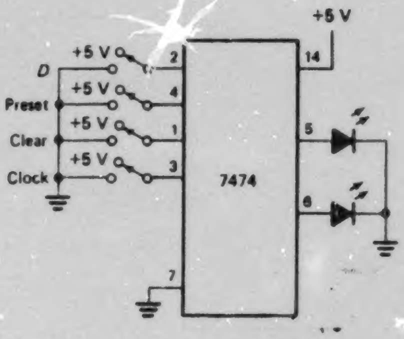
I. Equipment

A. 1 - 7474D flip-flop
B. 4 - SPDT switch
C. 2 - LEDs
D. +5V Power supply
E. Breadboard
F. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1


+5 V
+5 V
D
+5 V
Preset
+5 V
Clear
+5 V
Clock
2
4
1
3
14
5
6
7
7474

B. Turn on the power supply.

C. Fill in the following table by setting the preset (S) and clear (C) lines.

Input		Output		Expected Output	
S	C	Q	$\overline{Q}$	Q	$\overline{Q}$
0	1			1	0
1	0			0	1
0	0			ambiguous	

LAB SHEET #2

D. Now set both the S and C lines high.

E. With the clock (T) line high, change the D line from high to low to high. What is the state of the outputs?

Q=____________________ $\overline{Q}$=____________________

(NOTE: There should be no change.)

F. This time set the D line high and move the T line to low to high. What is the state of the outputs?

Q=____________________ $\overline{Q}$=____________________

G. Now set the D line to low. There should be no change until the T line is toggled. What is the state of the outputs?

Q=____________________ $\overline{Q}$=____________________

(NOTE: Only when the T line goes from high to low to high, rising edge-triggering, did the state of the flip-flop change. Show the instructor your results.)

H. Turn off the power supply.

I. Put up the equipment.

FLIP-FLOPS

UNIT IV

LAB SHEET #3 - CONSTRUCT A J-K FLIP-FLOP.

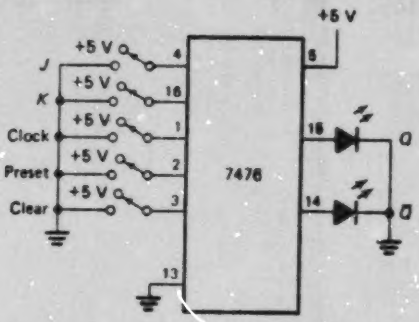
I. Equipment

- A. 1 - 7476 J-K flip-flop
- B. 5 - SPDT switch
- C. 2 - LEDs
- D. +5V Power supply
- E. Breadboard
- F. Hook-up wire

II. Procedure

A. Connect the circuit shown in Figure 1

FIGURE 1


+5 V
+5 V
J
+5 V
K
+5 V
Clock
+5 V
Preset
+5 V
Clear
4
16
1
2
3
13
7476
5
15
14
Q
Q

B. Turn on the power supply.

C. Using only the preset (S) and clear (C) fill in the following table:

Input		Output	
S	C	Q	$\overline{Q}$
0	1	1	0
1	0	0	1
0	0	unstable	

(NOTE: When both S and C are low, we have an ambiguous state. Care should be taken to avoid this state.)

D. Now make both the S and C line high.

LAB SHEET #3

E. Place a high on the J line and a low on the K line. Nothing should happen until the clock or T line is pulsed momentarily. What are the states of the outputs? Q=____________________

$\overline{Q}$=____________________________

F. Next place a low on the J and a high on the K line. Nothing should have happened until the T line has been pulsed. What is the state of the outputs?

Q=__________________________

$\overline{Q}$=____________________________

G. Now place a low on both the J and K lines. After pulsing the T line, what is the state of the outputs? Q=__________________

$\overline{Q}$=____________________________

(NOTE: The outputs should have remained constant.)

H. Place a high on both the J and K lines and pulse the T line. What is the state of the outputs? Q=______________________

$\overline{Q}$=____________________________

Pulse the T line again. Q=_____________________________

$\overline{Q}$=_____________________________

(NOTE: By pulsing the T line, the outputs should reverse. This is toggling. Show your results to the instructor.)

I. Turn off the power supply.

J. Put up your equipment.

FLIP-FLOPS

UNIT IV

TEST

NAME:____ SCORE:________________

1. Match terms associated with flip-flips to their definitions. Place the correct number in the blanks.

TEST

4. Describe how a J-K flip-flop works.

(NOTE: Test question 5 is lab sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

5. Demonstrate the ability to

   A. Construct and test a latch flip-flop.

   B. Construct and test a "D" flip-flop.

   C. Construct and test a J-K flip-flop.

6. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

FLIP-FLOPS

UNIT IV

TEST ANSWERS

1. a. 2

   b. 3

   c. 1

   d. 4

2.

Inputs		Outputs	
S	R	Q	$\overline{Q}$
0	0	Q_o	$\overline{Q}_o$
0	1	0	1
1	0	1	0
1	1	ambiguous	

3. The state changes only on the rising edge of the clock pulse.

Inputs		Outputs	
D	T	Q	$\overline{Q}$
0	0	Q_o	$\overline{Q}_o$
0	1	0	1
1	0	Q_o	$\overline{Q}_o$
1	1	1	0

4.

Inputs					Outputs	
S	C	J	K	T	Q	$\overline{Q}$
L	H	X	X	X	1	0
H	L	X	X	X	0	1
L	L	X	X	X	ambiguous	
H	H	0	0	H	Q_o	$\overline{Q}_o$
H	H	0	1	H	0	1
H	H	1	0	H	1	0
H	H	1	1	H	toggling	

5. Performance skills evaluated to satisfaction of the instructor.

DIGITAL ELECTRONICS

UNIT V

SEQUENTIAL LOGIC CIRCUITS

SEQUENTIAL LOGIC CIRCUITS

UNIT V

OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to use shift registers as storage, multipliers or dividers. The student should also be able to use binary and BCD counters in circuits. This knowledge will be shown by completing lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match the terms associated with sequential logic circuit to their definition.
2. Explain how to select a flip-flop binary counter to count to a specific number.
3. Explain how to determine how many flip-flops to use when a binary counter is to be used as a frequency divider.
4. Describe how to multiply a binary number by using a shift register.
5. List the different modes that shift registers can be used in.
6. Explain what is meant by a ripple counter.
7. Demonstrate the ability to
    - A. Wire and examine a shift register.
    - B. Use a register to store 8 bits.
    - C. Wire and examine a count-by-10 circuit.
    - D. Wire and examine a binary counter.
    - E. Wire and examine a 4-bit counter.
    - F. Wire and test an incrementing and decrementing asynchronous counter.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with infformation and lab sheets.

  C. Make transparencies.

  D. Discuss unit and specific objective.

  E. Discuss information and lab sheets.

  F. Demonstrate the use of flip flop as binary counter.

  G. Discuss uses of shift register.

  H. Assist students to construct shift register.

  I. Assist students in constructing and troubleshooting counter.

  J. Give test.

II. Student

  A. Read objective sheet.

  B. Study information sheet.

  C. Complete lab sheets.

  D. Take test.

SEQUENTIAL LOGIC CIRCUITS
UNIT V

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet.

  B. Information sheets.

  C. Lab sheets.

  D. Test.

  E. Answers to test.

II. References

  A. Pasahow, Edward I., Learning Digital Electronics Through Experiments, New York, New York, McGraw-Hill, 1982.

  B. Pasahow, Edward I., Digital Integrated Circuits, New YOrk New York McGraw-Hill Book Co. 1979.

  C. Leach, Donald P., Experiments in Digital Principle, New York, New York, McGraw-Hill Book Co., 1981

  D. Miller, Michael A., Digital Computers Electronics, New York, New York, McGraw-Hill Book Co., 1983.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Rising-edge-triggered - a device that changes state on the rising edge of a square wave impulse (ex. clock pulse).

B. Parallel shift - all inputs/outputs change state at the same time.

C. Serial shift - inputs/outputs change state one at a time.

D. Shift register - register device that moves information left or right one bit at a time.

E. BCD counter - a counter that counts 0-9.

F. Binary counter - counter made up of flip-flops to count from 0 to 2^n-1.

G. Ripple counter - a binary counter.

H. Synchronous circuit - a circuit that is clocked.

I. Enable - an input on an integrated circuit that allows the IC to function as it is wired.

J. Increment/decrement counter - a counter that can count up or down.

K. Asynchronous circuit - a circuit that uses no clock

II. To determine how many flip-flops to include in a binary counter, make sure that the number that is to be counted up to is less than $2^n - 1$. Where "n" is the number of flip-flop. Example: to count to 250. Let "n" = 8. Then $2^8 - 1 = \underline{255}$.

III. A binary counter made up of flip-flops can be used as a frequency divider. To determine how many times a frequency will be divided by how many flip-flops, take the number of flip-flops (n) and put into the equation 2^n = number the frequency will be divided by. Example: Five flip-flops; n=5; therefore $2^n = 32$ and the frequency will be divided by 32.

IV. A shift register can be used as a multiplier of a binary number by shifting the number to the left. Example: $00010000_2 = 16_{10}$

INFORMATION SHEET

a. By shifting the number two places to the left gives; $01000000_2 = 64_{10}$ This is the same as multiplying 16x4=64.

b. 00000011_2 shifted 4 places to the left gives: $00110000_2=48_{10}$ or 3x16=48.

c. Use the formula 2 to find the multiplier.

V. Shift registers can be used in four modes.

A. Serial in serial out SISO
B. Parallel in parallel out PIPO
C. Serial in parallel out SISO
D. Parallel in serial out PIPO

VI. In a binary counter, after an internal flip-flop is set, it in turn sets the next flip-flop which in turn sets the next and so on, giving a ripple effect. This is called a ripple counter.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

LAB SHEET #1 - WIRE AND EXAMINE A SHIFT REGISTER

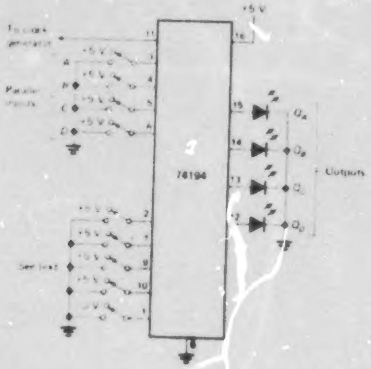
I. Equipment

A. 1 - 74194 Shift register
B. 4 - LEDs
C. 9 - SPDT switch
D. Clock generator (1 sec.)
E. +5V power supply
F. Breadboard
G. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1


+5 V
To clock generator
11
16
+5 V
A
3
+5 V
B
4
Parallel inputs
+5 V
C
5
+5 V
D
6
74194
15
Q_A
14
Q_B
Outputs
13
Q_C
12
Q_D
+5 V
2
+5 V
7
+5 V
See text
9
+5 V
10
+5 V
1

B. Turn on power supply.

C. Disconnect the clock temporarily.

D. Ground pin 1 momentarily to clear all outputs low.

E. Set pins 9 and 10 high.

F. Set O_A - high; Q_B = low; Q_C = high; Q_D = low.

G. Turn on the clock.

H. The outputs should agree with the inputs.

I. Turn off the clock.

J. Set pin 2 to high and ground pin 9.

K. Pulse the clock low then high. This register is rising-edge-triggered.

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LAB SHEET #1

L. The output should now read Q_A = high; Q_B= high; Q_C = low; Q_D = high.

M. How have the outputs changed? ______________________________

____

N. Pin 2 in the shift right control (ground pin 2).

O. Now manually apply a low to high to the clock pin (11).

P. The output should be Q_A = low; Q_B = high; Q_C = high; Q_D = low. There has been a shift right but Q_A has been set to the state of pin 2.

Q. Now set the shift left pin (7) high. Manually apply a clock pulse. Q_A = high; Q_B = high; Q_C = low; Q_D = high. Again, Q_D has taken the state of pin 7.

R. Now set pin 7 low and manually clock pin 11. Q_A = high; Q_B = low; Q_C = high; Q_D = low; Q_D has the state of pin 7.

(NOTE: Explain your results to the instructor.)

S. Turn off your power supply.

T. Put up your equipment.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

LAB SHEET #2 - USE A REGISTER TO STORE 8 BITS

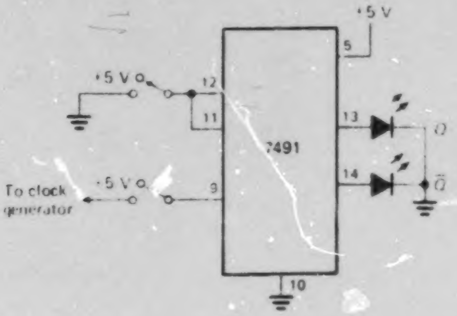
I. Equipment

- A. 1 - 7491 Shift register
- B. 2 - SPDT switch
- C. 2 - LEDs
- D. Clock (1 sec)
- E. +5V Power supply
- F. Breadboard
- G. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1



B. Turn on the power supply.

C. Connect pin 12 and 11 to a high.

D. Turn on the clock. What happens? Q = ______________________

$\overline{Q}$ = ______________________________________

E. After a delay the output should go Q = high $\overline{Q}$ = low. The delay should be about 8 seconds as the high was shifted right one bit at a time and finally began reading out.

F. Disconnect pin 12 or 11. What happens after about 8 seconds?
Q = ______________________ $\overline{Q}$ = ______________________

(NOTE: Explain your observation to the instructor.)

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LAB SHEET #2

G. Turn off the power supply.

H. Put up your equipment.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

LAB SHEET #3 - WIRE AND EXAMINE A COUNT-BY-10 CIRCUIT.

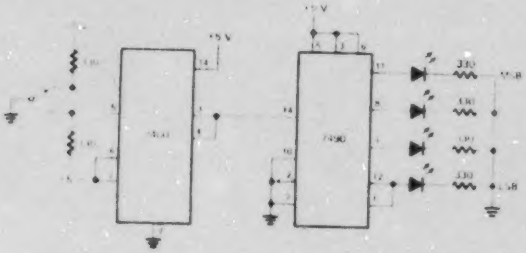
I. Equipment

- A. 1 - 7400 NAND gate
- B. 1 - 7490 Decade counter
- C. 6 - 330 Resistors
- D. 4 - LEDs
- E. 1 - Pushbutton switch
- F. +5V Power supply
- G. Breadboard
- H. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1



B. Turn on the power supply.

C. Manually open and close the switch on pins 1 and 5 on the 7400.
The LEDs are ____
____.

D. In this configuration the BCD counter, counts from 0-9, then starts over again.

E. Now disconnect pins 1 and 14 of the 7490.

F. Connect the output of the 7400 to pin 1 of the 7490.

LAB SHEET #3

G. Connect pin 14 to pin 11 of the 7490.

H. Begin opening and closing the switch. After how many switch closures does the LED on pin 12 light up? ____________________

In this configuration the counter has become a ________________.

(NOTE: Show your results to the instructor.)

I. Turn off the power supply.

J. Put up the equipment.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

LAB SHEET #4 - WIRE AND EXAMINE A BINARY COUNTER.

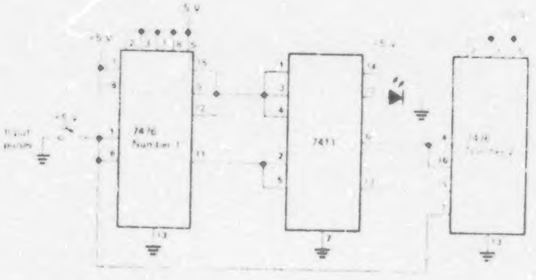
I. Equipment

- A. 2 - 7476 J-K flip-flops
- B. 1 - 7411 AND gate
- C. 1 - LED
- D. 1 - SPDT switch
- E. 1 - Voltmeter
- F. +5V Power supply
- G. Breadboard
- H. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1

FIGURE 1


+5 V
+5 V
2 3 7 16 5
7476 Number 1
7411
+5 V
7476 Number 2
Input pulses
15
12
11
1
3
4
2
5
14
6
4
16
13
7
13

B. Turn on the power supply.

C. With the voltmeter on pin 15 (7476) open and close the SPDT switch. What does the voltmeter show? ____________________

D. Continue the switching for at least 10 closures. Does anything happen to the LED? ____________________

How often? ____________________

E. Attach the voltmeter to pin 11 (7476#1).

F. Begin with the LED on and count the number of switchings before pin 11 goes low. Count = ____________________.

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LAB SHEET #4

G. Switch the voltmeter to pin 15 (7476#2). With the LED on, how many switchings before the voltmeter goes low? ________________.

H. The output of flip-flop 1 changes state after every switch closure. The second flip-flop changes after every other closure while the third flip-flop changes after fourth closure. This is an example of a ripple counter.

(NOTE: Show your results to the instructor.)

I. Turn off your power.

J. Put up your equipment.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

LAB SHEET #5 - WIRE AND EXAMINE 4-BIT COUNTERS

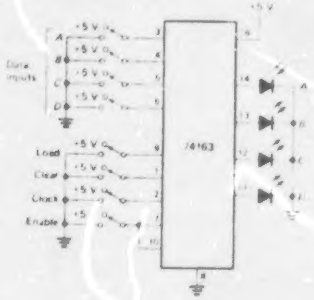
I. Equipment

A. 1 - 74163 Counter
B. 4 - LEDs
C. 8 - SPST Switch
D. +5V Power supply
E. Breadboard
F. Hook-up wire

II. Procedure

A. Wire the circuit in Figure 1.

FIGURE 1


+5 V
Data inputs
A
B
C
D
+5 V
+5 V
+5 V
+5 V
3
4
5
6
Load
Clear
Clock
Enable
+5 V
+5 V
+5 V
+5
9
1
2
7
10
74163
16
14
13
12
11
A
B
C
D
8

B. Turn on the power supply.

C. Set the following switches:

Clock	H
Load	H
Enable	L
Clear	H

D. To turn off the LEDs, set clear low, input a clock pulse and then put clear back high.

E. Now set the data inputs:

A	L
B	L
C	H
D	H

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LAB SHEET #5

(NOTE: This setting represents $C_{16} = 12_{10}$.)

F. Now switch load to low input a clock pulse and then put load back high. How do the outputs look?

A = ______________________ B = ______________________

C = ______________________ D = ______________________

G. Does impulsing the clock at this time make any difference?

____

H. With the preset valve of 12_{10} in the counter, set the enable high? ____

I. Now impulse the clock. What change if any now occurs?

____

J. Try reset the counter to other values and counting. What happens after sixteen pulses? ______________________________

(NOTE: Show the instructor your results.)

K. Turn off the power.

L. Put up your equipment.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

LAB SHEET #6 - WIRE AND TEST AN INCREMENTING AND DECREMENTING ASYNCHRONOUS COUNTER

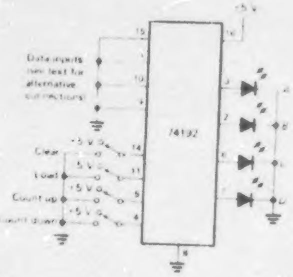
I. Equipment

A. 1 - 74192 counter
B. 4 - SPDT Switch
C. 4 - LEDs
D. +5V Power supply
E. Breadboard
F. Hook-up wire

II. Procedure

A. Connect the circuit Figure 1.

FIGURE 1


+5 V
15
16
Data inputs
(see text for
alternative
connections)
1
10
9
74192
+5 V
Clear
14
5 V
Load
11
+5 V
Count up
5
+5 V
Count down
4
3
2
6
7
8
A
B
C
D

B. Initially plan the control switches:

Clear	L
Load	H
Count up	H
Count down	H

C. Clear the outputs. Set clear to high then back to low.

D. Set the counter to zero by changing load from high to low to high.

E. Move the count-up switch to high to low several turns. What happens to the outputs? ______________________________

What happens after the tenth pulse? ______________________

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LAB SHEET #6

F. Now switch the count-up switch to high and pulse the count-down switch. What happens? ______________________________

____

(NOTE: Show your results to the instructor.)

G. Turn off the power.

H. Put up your equipment.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

TEST

NAME____SCORE__________

1. Match terms associated with sequential logic to the definitions. Place the correct number in the blank.

_____a. A device that changes state on the rising edge of a square wave impulse.

_____b. A counter that can count up or down.

_____c. A counter that counts 0-9.

_____d. Counter made up of flip-flops to count from 0 to 2^n-1.

_____e. An input on an integrated circuit that allows the IC to function as it is wired.

_____f. A binary counter.

_____g. A circuit that is clocked.

_____h. Register device that moves information left or right one bit at a time.

_____i. All inputs/outputs change state at the same time.

_____j. Inputs/outputs change state one at a time.

_____k. A circuit that uses no clock.

1. Asynchronous circuit
2. Ripple counter
3. Synchronous circuit
4. Enable
5. Increment/decrement counter
6. Rising-edge-triggered
7. Serial shift
8. BCD counter
9. Parallel shift
10. Shift register
11. Binary counter

2. How many flip-flops will be needed to count to 6000_{10}?

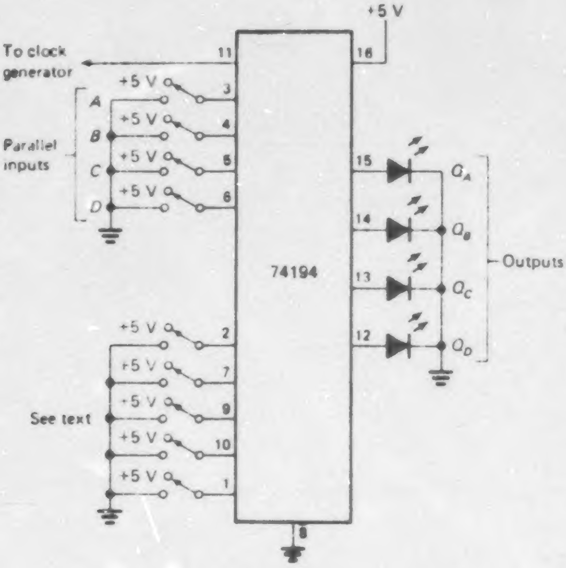
3. What will a frequency be divided by if the frequency is put into a counter made up of six flip-flops?

TEST

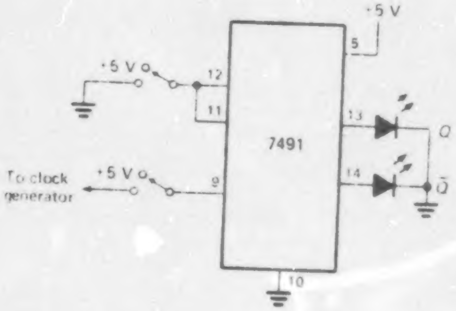
4. A number is shifted 5 places to the left. The number has been multiplied by ______________________.

5. Label the following figures as to whether they are: SISO, SIPO, PISO, PIPO.

A. ____


+5 V
To clock
generator
11
16
+5 V
3
A
+5 V
4
B
Parallel
inputs
+5 V
5
C
+5 V
6
D
15
Q_A
14
Q_B
74194
Outputs
13
Q_C
12
Q_D
+5 V
2
+5 V
7
+5 V
9
See text
+5 V
10
+5 V
1
8

B. ____


+5 V
5
+5 V
12
11
13
Q
7491
To clock
generator
+5 V
9
14
$\bar{Q}$
10

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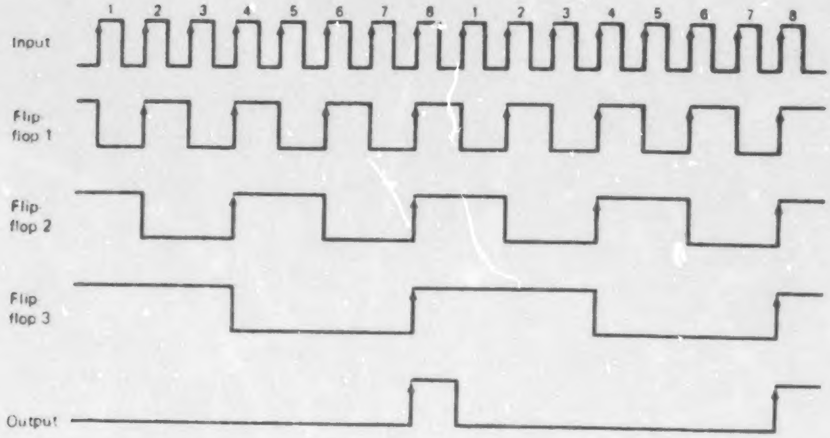
TEST

6. A. Below is the timing diagram for ___________ binary counter.

   B. The output will be high how often? ____________________

   C. Flip-flop 2 will be high how often? ____________________


1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
Input
Flip flop 1
Flip flop 2
Flip flop 3
Output

7. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

SEQUENTIAL LOGIC CIRCUITS

UNIT V

TEST ANSWERS

1. a. 6
   b. 5
   c. 8
   d. 11
   e. 4
   f. 2
   g. 3
   h. 10
   i. 9
   j. 7
   k. 1

2. $2^{n}-1 < 6000$

   $2^{1B}-1 = 8191$

   $2^{12}-1 = 4095$

   Therefore 13 flip-flops will be needed.

3. $2^{6} = 64$

   The frequency will be divided by 64.

4. 32

5. A. PIPO
   B. SISO

6. A. ripple
   B. every 8 inputs
   C. every 4 inputs

DIGITAL ELECTRONICS

UNIT VI

COMBINATIONAL LOGIC CIRCUITS

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to wire and use multiplers, demultiplexers, encoder, decoders, code converter and memories. This knowledge will be shown by completing lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with combinational logic circuits to their correct definition.
2. List at least three uses for decoders.
3. List three applications for a multiplexer circuit.
4. List three applications for the Exclusive Or circuit.
5. Name different types of code converters.
6. Describe a Read Only Memory
7. Demonstrate the ability to
    - A. Decoding BCD to binary.
    - B. Compare BCD number using a comparator.
    - C. Wire and examine adders.
    - D. Identify parity with a parity generator
    - E. Examine a memory.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide student with objective sheet.

  B. Provide students with information and lab sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information and lab sheets.

  F. Demonstrate logic circuitsused as decoders, MUX. converter, and memory.

  G. Assist student constructing and troubleshooting BCD to binary logic circuits.

  H. Assist students in constructing and troubleshooting memory and adder logic circuit.

  I. Give test.

II. Student

  A. Read objective sheet.

  B. Study information sheets.

  C. Complete lab sheets.

  D. Take test.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet.

B. Information sheets.

C. Lab sheets.

D. Test.

E. Answers to test.

II. References

A. Pasahow, Edward I., Learning Digital Electronics Through Experiments, New York, New York, McGraw-Hill, 1982.

B. Pasahow, Edward I., Digital Integrated Circuits, New YOrk New York McGraw-Hill Book Co. 1979.

C. Leach, Donald P., Experiments in Digital Principle, New York, New York, McGraw-Hill Book Co., 1981

D. Miller, Michael A., Digital Computers Electronics, New York, New York, McGraw-Hill Book Co., 1983.

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CONBINATIONAL LOGIC CIRCUITS

UNIT VI

INFORMATION SHEET

I. Terms and definitions

   A. Decoder - a logic circuit that can detect a specific bit or bits.

   B. Encoder - a logic circuit that takes a bit or bits and generates a specific output code.

   C. Multiplexer - a logic circuit that can select and deliver inputs to an output.

   D. Demultiplexer - a logic circuit that delivers a specific input to multiple outputs.

   E. Exclusive Or - a two input circuit that outputs a binary one if one of the inputs is a binary one.

   F. Exclusive Nor - a two input circuit that outputs a binary zero if one of the inputs is a binary one.

   G. Code converter - a logic circuit that converts one code to another code.

   H. Read Only Memory (ROM) - a logic circuit that is used to permanently store information.

II. Uses of decoders

   A. BCD to decimal - four BCD input bits are decoded to decimal 0-9.

   B. Binary to octal - three binary bits are converted to octal 0-7.

   C. BCD to 7 regiment readout displays - four BCD inputs generate the a-g readout cods.

III. Applications of multiplexers

   A. Parallel to serial conversion - input bits in parallel form are selected one at a time in sequence to the output.

   B. Serial binary bit generator - through wiring of the MUX only specific groups of bits are available to the output.

   C. Boolean function generator - by applying a binary 1 to one of eight possibilities, a Boolean product will be available at the output.

INFORMATION SHEET

IV. Uses for Exclusive Or circuits.

A. Half adder circuit - this circuit will produce a binary zero with a carry one if both inputs are binary zero or one. Otherwise the output will be one with no carry.

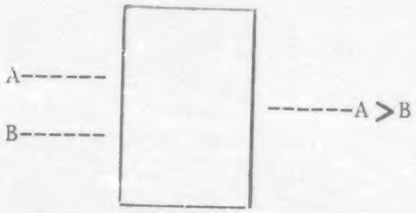
B. Parity generator or checker - this circuit will generate a binary one for either odd or even parity to aid in error checking.

C. Binary comparator - the circuit generates a binary zero if both parallel inputs are equal. By selecting which input is one while the other is zero a comparison can be made to decide which input is large.

EXAMPLE:

A = 4

B = 3



V. There are several code converters with the most common being the binary to BCD or BCD to binary. Others are: binary to gray, gray to binary, 8421 BCD to XS3, XS3 to 8421BCD, and ASCII to EBCD1C, EBCD1C to ASCII.

VI. Read Only Memories

A. Components

1. Adders decodes
2. Storage elements
3. Output circuits

B. Uses

1. Random logic
2. Code conversion
3. Arithmetic operation

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

LAB SHEET #1 - DECODE BCD TO BINARY OUTPUTS

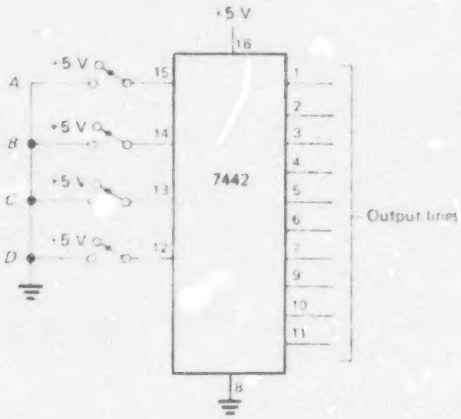
I. Equipment

A. 1 - 7442 decoder
B. 4 - SPST switch
C. 1 - Voltmeter
D. +5V Power supply
E. Breadboard
F. Hook-up wire

II. Procedure

A. Construct the circuit in Figure 1.

FIGURE 1


+5 V
16
+5 V
A
15
+5 V
B
14
+5 V
C
13
+5 V
D
12
7442
1
2
3
4
5
6
7
9
10
11
Output lines
8

B. Turn on the power supply.

C. Set inputs A, B, C, D to low. Using the voltmeter test the outputs. What is the state of the outputs?

____

D. Set A input high and B, C, D low. What is the state of the outputs now? ____

(NOTE: First pin 1 was low while the other pins 2 - 11 were high. Second pin 2 was low while pins 1 - 11 were high.)

LAB SHEET #1

E. Now complete the following table for all other output pins.

Pins	Input				Output pin									
#	A	B	C	D	1	2	3	4	5	6	7	9	10	11
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
1	0	0	0	1	1	0	1	1	1	1	1	1	1	1
2														
3														
4														
5														
6														
7														
8														
9														

(NOTE: Show the instructor your results.)

F. Turn off the power.

G. Put up your equipment.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

LAB SHEET #2 - COMPARE BCD NUMBERS USING A COMPARATOR.

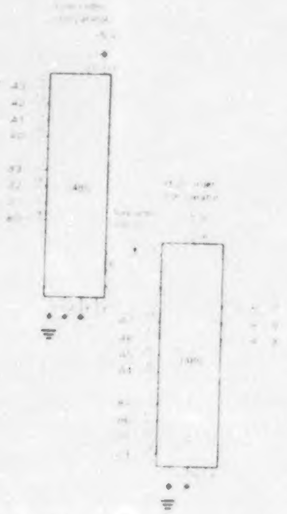
I. Equipment

- A. 1 - 7485 Comparator
- B. 4 - SPDT Switch
- C. 1 - Voltmeter
- D. +5V Power supply
- E. Breadboard
- F. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1



(NOTE: Pins 9, 10, 11, 12 are high therefore they will always be equal.)

B. Set pin 15 high. Which output is high 5, 6, 7?______________

(NOTE: This shows A>B)

C. Reset the input and set pin 1 high. Which output is high now? ____.

(NOTE: Now A<B.)

D. Reset the input and set pin 13 high. Which output is high?

____

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LAB SHEET #2

E. Reset the input and set pin 14 high. Which output is high?

____

F. Try other combinations which output is high. When are all inputs the same? ______________________________________

(NOTE: Show your results to the instructor.)

G. Turn off the power.

H. Put up your equipment.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

LAB SHEET #3 - WIRE AND EXAMINE ADDERS

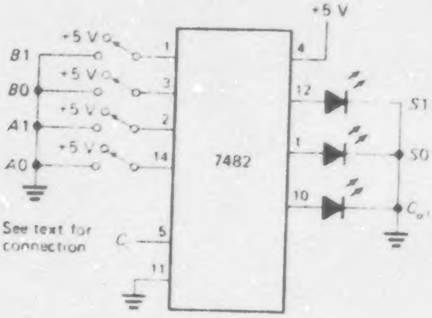
I. Equipment

A. 1 - 7482 Adder
B. 3 - LEDs
C. 1 - 7405 Inverter
D. 4 - SPDT Switch
E. 1 - Voltmeter
F. +5 Volt power supply
G. Breadboard
H. Hook-up wire

II. Procedure

A. Wire the circuit in Figure 1.

FIGURE 1


+5 V
+5 V
+5 V
+5 V
+5 V
B1
B0
A1
A0
1
3
2
14
4
12
1
10
5
11
7482
S1
S0
C_o
C
See text for connection

B. Turn on the power.

C. Ground pin 5, the input carry.

D. By using the SPDT switch complete Table 1, Column B.

LAB SHEET #3

D. (Conti.) TABLE 1

A Input				B Output			C Output		
AO	BO	AI	BI	S_o	S_1	C_{o1}	S_o	C_1	C_{o1}
0	0	0	0	0	0	0	1	0	0
1	0	0	0	1	0	0	0	1	0
0	1	0	0						
1	1	0	0						
0	0	1	0						
1	0	1	0						
0	1	1	0						
1	1	1	0						
0	0	0	1						
1	0	0	1						
0	1	0	1						
1	1	0	1						
0	0	1	1						
1	0	1	1						
0	1	1	1						
1	1	1	1						

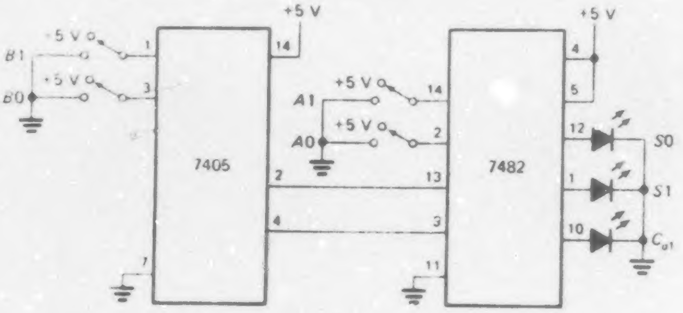
E. Next connect the carry pin (5) to +5V and complete Column C in Table 1. Be sure to observe the difference made by having a constant carry.

(NOTE: Actually the carry pin is used to cascade adders. Have the instructor evaluate the results.)

F. Turn off the power supply.

G. Connect inverters to the adder as shown in Figure 2.

FIGURE 2


+5 V
+5 V
+5 V
B1
+5 V
B0
1
3
14
7405
2
4
7
+5 V
A1
14
+5 V
A0
2
13
3
11
7482
4
5
12
1
10
S0
S1
C_{o1}

LAB SHEET #3

H. Connect the carry (5) to +5V.

I. Set the inputs to:

AD = 1 B0 = 1
A1 = 0 B1 = 0

Does the output look like S0 = 0, S1 = 0, C01 = 1 ?

J. Set the inputs to:

A0 = 1 B0 = 1
A1 = 1 B1 = 0

Is the output: S0 = 0, S1 = 0, C01 = 1 ?

K. In both cases the results are zero which fits Table 2.

TABLE 2

	2's complement	
Positive numbers	01	= 1_{10}
	00	= 0_{10}
Negative numbers	11	-1_{10}
	10	-2_{10}

L. In step I

A = 01
B = $\underline{11}$
S = 00 +0
C1

M. In step J

A = 11
B = 01
S = 10 = +C

(NOTE: Show your results to the instructor.)

N. Turn off the power.

O. Put up your equipment.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

LAB SHEET #4 - IDENTIFY PARITY WITH A PARITY GENERATOR.

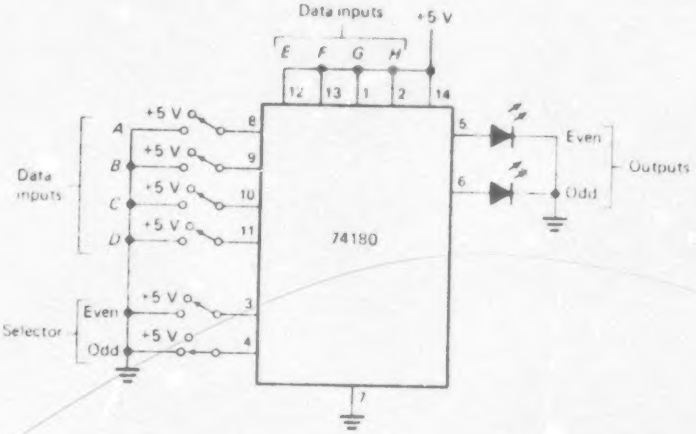
I. Equipment

A. 1 - 74180 parity generator
B. 6 - SPDT Switches
C. 2 - LEDs
D. 1 - Voltmeter
E. +5V Power supply
F. Breadboard
G. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1


Data inputs
+5 V
E
F
G
H
12
13
1
2
14
Data inputs
A
B
C
D
+5 V
+5 V
+5 V
+5 V
8
9
10
11
74180
Selector
Even
Odd
+5 V
+5 V
3
4
7
5
6
Even
Odd
Outputs

B. Turn on the power supply.

C. Set input A - D high.
Note the output levels - Pin 5= ____________ Pin 6 = ____________

D. Now open A. What are the output levels now - Pin 5 = ____________
Pin 6 = ______________

(NOTE: In the first case, the circuit was set for odd parity but there was even. In the second case, the circuit was set for odd parity but there was odd.)

LAB SHEET #4

E. Now reverse the setting on pins 3 and 4 and repeat steps C and D. Did the levels reverse?

____

F. This time ground A and B. The output level should be pin 5 = high and pin 6 = low or even parity which there is.

G. Set both pin 3 and pin 4 high. What are the output levels?

Pin 5 = _______________ Pin 6 = _______________

(NOTE: In the case where both selector pins are the same, the output levels are meaning less. Show your result to the instructor.)

H. Turn off the power.

I. Put up your equipment.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

LAB SHEET #5 - EXAMINE A MEMORY

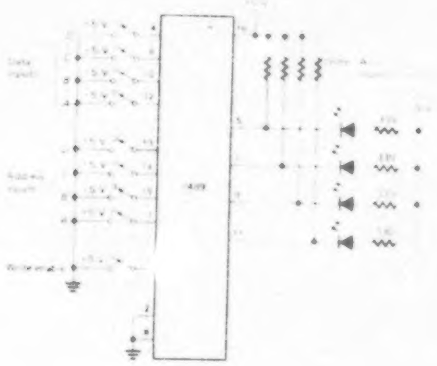
I. Equipment

- A. 1 - 7489 RAM
- B. 4 - LEDs
- C. 4 - 2K Resistor
- D. 4 - 330 Resistor
- E. 9 - SPDT Switch
- F. +50 Power supply
- G. Breadboard
- H. Hook-up wire

II. Procedure

A. Connect the circuit in Figure 1.

FIGURE 1


Data inputs
Address inputs
Write enable
+5 V
7489
4
6
10
12
15
14
13
1
16
5
7
9
11
2
8

B. Turn on the power.

C. Set pin 3 high.

D. Set address bits to zero which indicates address zero.

E. Now set data inputs to zero.

F. By grounding pin 3, 0000 is read into address zero.

G. Set pin 3 back to high.

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LAB SHEET #5

H. Complete Table 1 by setting the address, data line and enable line.

TABLE 1

Address				Data				LED			
D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	1	0	0	0	1	1	1	1	0
0	0	1	0	0	0	1	0	1	1	0	1
0	0	1	1	0	0	1	1	1	1	0	0
0	1	0	0	0	1	0	0	1	0	1	1
0	1	0	1	0	1	0	1	1	0	1	0
0	1	1	0	0	1	1	0	1	0	0	1
0	1	1	1	0	1	1	1	1	0	0	0
1	0	0	0	1	0	0	0	0	1	1	1
1	0	0	1	1	0	0	1	0	1	1	0
1	0	1	0	1	0	1	0	0	1	0	1
1	0	1	1	1	0	1	1	0	1	0	0
1	1	0	0	1	1	0	0	0	0	1	1
1	1	0	1	1	1	0	1	0	0	1	0
1	1	1	0	1	1	1	0	0	0	0	1
1	1	1	1	1	1	1	1	0	0	0	0

I. Now with the enable switch high, look at several addresses to make sure the contents are as saved.

(NOTE: Show your results to the instructor.)

J. Turn off the power.

K. Put up your equipment.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

TEST

NAME____ SCORE______________

1. Match terms associated with combinational logic circuits to their correct definition. Write the correct number in the blank.

_____ a. A logic circuit that is used to permanently store information.

_____ b. A logic circuit that delivers a specific input to multiple outputs.

_____ c. A logic circuit that takes a bit or bits and generates a specific output code.

_____ d. A logic circuit that converts one code to another code.

_____ e. A two input circuit that outputs a binary one if one of the inputs is a binary one.

_____ f. A logic circuit that can detect a specific bit or bits.

_____ g. A two input circuit that outputs a binary zero if one of the inputs is a binary one.

_____ h. A logic circuit that can select and deliver inputs to an output.

1. Read Only Memory (ROM)
2. Multiplexer
3. Decoder
4. Exclusive Nor
5. Encoder
6. Demultiplexer
7. Code Converter
8. Exclusive Or

2. List three uses for decoders.

a.

b.

c.

3. List three applications for a multiplexer.

a.

b.

c.

TEST

4. List three applications for the Exclusive Or circuits.

   a.

   b.

   c.

5. Name four different code converters.

   a.

   b.

   c.

   d.

6. Describe a ROM.

(NOTE: Test question 7 involves lab sheets. They are an important part of this unit. If they have not been completed, check with the instructor.)

7. Demonstrate the ability to

   A. Decode BCD to binary.

   B. Compare BCD numbers using a comparator.

   C. Wire and examine adders.

   D. Identify parity with a parity generator.

   E. Examine a memory.

8. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

COMBINATIONAL LOGIC CIRCUITS

UNIT VI

TEST ANSWERS

1. a. 1

   b. 6

   c. 5

   d. 7

   e. 8

   f. 3

   g. 4

   h. 2

2. a. BCD to decimal

   b. Binary to octal

   c. BCD to readout display

3. a. Parallel to serial conversion

   b. Serial binary bit generator

   c. Boolean funtion generator

4. a. Half-adder

   b. Parity generator

   c. Binary Comparator

5. a. Binary to BCD

   b. Binary to gray

   c. 8421 BCD to XS3
   d. ASCII to EDCDIC
6. Components

   a. Address decoder

   b. Storage elements

   c. Output circuit

   Uses

   a. Random logic
   b. Code conversion

   c. Arithmetic operation

TEST ANSWERS

7. Performance shall be evaluated to satisfaction of instructor.

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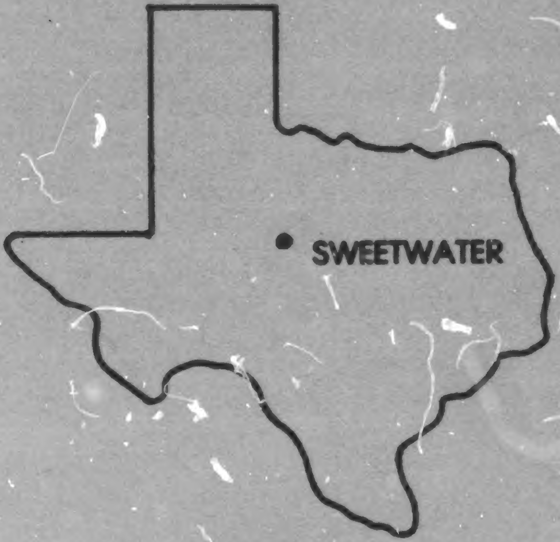
"CURRICULUM DEVELOPMENT - POST-SECONDARY ELECTRO-MECHANICAL TECHNOLOGY"



PART III

TEXAS STATE TECHNICAL INSTITUTE
SWEETWATER, TEXAS

1984

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POWER DISTRIBUTION

UNIT I

BASICS OF POWER DISTRIBUTION

BASICS OF POWER DISTRIBUTION

UNIT I

OBJECTIVE

After completing this unit, the student should be able to determine the power being delivered to a customer and discuss how power is delivered from the service entrance to the load.

SPECIFIC OBJECTIVES

After completing this unit, this student should be able to

1. Match terms associated with basics of power distribution to their definitions.
2. Locate terms associated with basics of power distriubtion in Article 100 of the National Electric Code.
3. Demonstrate the ability to determine insulation and conductor types.

BASIC OF POWER DISTRIBUTION

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure, information, labs and assignment sheets.

   C. Make transparencies.

   D. Discuss unit and specific objective.

   E. Discuss information, assignment, and lab sheets.

   F. Demonstrate safety procedures set forth in the National Electric Code.

   G. Demonstrate the use of the National Electric Code.

   H. Assist students in selective insulator and conductor type.

   I. Give test.

II. Student

   A. Read objective sheet.

   B. Complete the procedure sheet.

   C. Take test.

BASICS OF POWER DISTRIBUTION

UNIT I

INSTRUCTIONAL MATERIAL

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Information sheets.
- D. Assignment sheets.
- E. Lab sheets.
- F. Test.
- G. Answers to assignment sheets.
- H. Answers to test.

II. References

- A. Graham, Kennard C., Industrial and Commercial Wiring, Chicago, IL, American Technical Society, 1963.
- B. Smith, Robert L., Electrical Wiring, Industrial, Albany, New York, Delmar Publishing, 1984.
- C. [illegible]enk, John D., Handbook of Simplified Electrical Wiring Design, Englewood Cliffs, New Jersey, Prentice - Hall, 1975.
- D. Fardo and Prewit, Electrical Experimentation & Practical Applications, Indianapolis, IN, Howard W. Sams & Co., 1978.
- E. Patrick and Fardo, Experimenting with Industrial Electrical System, Indianapolis, IN, Howard W. Sams & Co., 1978.
- F. Patrick and Fardo, Electrical Power System Technology, Indianapolis, IN, Howard W. Sams, 1979.

G. Palmquist, Roland E., Questions and Answers for Electrician Examinations, Indianapolis, IN., Howard W. Sams, 1979.

III. Related Material

A. National Electric Code, Quincy, MA, National Fire Protection Association, 1983.

BASICS OF POWER DISTRIBUTION

UNIT I

PROCEDURE SHEET

_____1.	Study	Information Sheet - Terms and Definitions
_____2.	Study	Chapter I, *Basics of Electrical Power Distribution, Handbook of Simplified Electrical* Wiring Design.
_____3.	Complete	Assignment Sheet #1 - Using the National Electric Code.
_____4.	Stop	Have your instructor evaluate your assignment sheet. If your instructor is satisfied with your performance, continue to Step 5; otherwise repeat Steps 2 - 4.
_____5.	Complete	Lab Sheet #1. Determining Insulating and Conductor types.
_____6.	Stop	Have your instructor observe the results of your experiment. If the instructor is satisfied, proceed to step 7. Otherwise, repeat steps 5 and 6.
_____7.	Review	Chapter 1 in your text and Assignment Sheet #1.
_____8.	Take	Basics of Power Distribution test.

BASICS OF POWER DISTRIBUTION

UNIT I

INFORMATION SHEET

Terms and definitions

A. National Electric Code (NEC) - a set of minimum standards for electrical installation developed by the National Fire Protection Association (NFPA) and updated every three years. (NOTE: each locale may interpret the code differently.)

B. Service drop - the conduction brought into the customer service entrance.

C. 277-480 V three-phase distribution - a four wire system and primarily for lighting large industrial plants.

D. 240 v three-phase distribution - used typically in low horsepower motor.

E. 480 v three-phase distribution - used typically for high horsepower motor.

F. High-voltage distribution - special application of the order of 2400, 4800, 4160, etc., are for exceptional purposes.

G. Service entrance - each utility company has its own requirement as to service entrances. Common elements are necessary watt-hour meter main disconnect means overcurrent device and a system ground. Two types are: overhead and underground.

H. Service entrance box - known as the switch box, pull box or main box.

I. Overcurrent protection - protection against overloads and short circuits is provided by fuses, circuit breakers and ground fault circuit interrupter (GFCI).

J. Ground fault circuit interrupter - a device that detects small amounts of current leakage and interrupts the circuit when the leakage reaches a certain level.

K. Branchcircuit - a set of conductors that extend beyond the last overcurrent device in a system.

L. Feeder - a set of conductors that supply a group of travel circuits. Feeders receive power from service entrance.

M. Panelboards - assemblies of overcurrent device contained in a cabinet. Feeders deliver power to panelboards which in turn deliver power to branch circuits.

INFORMATION SHEET

N. Subfeeders - a panelboard away from the service entrances. The switchboard is supplied with a feeder from the service entrance which in turn supplies branch circuits.

BASICS OF POWER DISTRIBUTION

UNIT I

ASSIGNMENT SHEET #1 - THE NATIONAL ELECTRIC CODE

Answer the following questions using the National Electric Code, Article 100.

1. What is meant by "accessible"?

2. What is meant by accessible equipment?

3. What is a pressure connector?

4. What is meant by "dust-tight"?

5. What is meant by "explosion-proof"?

ASSIGNMENT SHEET #1

6. What is meant by "service lateral"?

7. What is meant by a "motor-circuit switch"?

BASICS OF POWER DISTRIBUTION

UNIT I

ASSIGNMENT SHEET # - THE NEC AND HAZARDOUS LOCATIONS

1. What is a Class I location? (EC500-4)

2. What are Class II locations ? (NEC500-5)

3. What are Class III locations ? (NEC500-6)

4. In Class I, Division I areas, what type of wiring must be used? (NEC501-4)

5. In Class I areas, why is sealing needed in conduit systems and not in Type MI cable systems? (NEC501-5)

6. Do Class I locations need to be grounded? (NEC501-16)

ASSIGNMENT SHEET #2

7. Name some precautions that must be taken when transformers are used in Class II, Division 1 location? (NEC502-2)

8. Is grounding and bonding necessary in Class II locations? (NEC502-16)

9. In class III, Division I locations, what type of wiring is required? (NEC503-3)

10. Commercial garages may use what kind of material for wiring? (NEC511-5)

11. What type of wiring is required in all aircraft hanger locations? (NEC513-3)

12. Are there restriction on switching circuits leading to or going through a gasoline-dispensing pump? (NEC514-5)

13. What is a Critical Branch? (NEC517-2)

BASICS OF POWER DISTRIBUTION

UNIT II

LAB SHEET #1 - DETERMINING INSULATION AND CONDUCTOR TYPES

I. Equipment

  A. American wire gauge
  B. Conductor samples

II. Procedure

  A. Get at least five sample conductors from your instructor.

  B. Use the AWG to measure the diameter of your samples. Record the results:

    1.

    2.

    3.

    4.

    5.

  C. Use the AWG table below to determine how much cement each conductor above will carry.

    1.

    2.

    3.

    4.

    5.

(AWG table - next page)

LAB SHEET 1

	Size (AWG or MCM)	Area (cmil)	Number Wires	Diameter Each Wire (in)	DC Resistance at 25°C, 77°F (Ω/1000 ft)	
					Copper	Aluminum
AWG Sizes	18	1620	Solid	0.0403	6.51	10.7
	16	2580	Solid	0.0508	4.10	6.72
	14	4110	Solid	0.0641	2.57	4.22
	12	6530	Solid	0.0808	1.62	2.66
	10	10,380	Solid	0.1019	1.018	1.67
	8	16,510	Solid	0.1285	0.6404	1.05
	6	26,240	7	0.0612	0.410	0.674
	4	41,740	7	0.0772	0.259	0.424
	3	52,620	7	0.0867	0.205	0.336
	2	66,360	7	0.0974	0.162	0.266
	1	83,690	19	0.0664	0.129	0.211
	0	105,600	19	0.0745	0.102	0.168
	00	133,100	19	0.0837	0.0811	0.133
	000	167,800	19	0.0940	0.0642	0.105
	0000	211,600	19	0.1055	0.0509	0.0836
MCM Sizes	250	250,000	37	0.0822	0.0431	0.0708
	300	300,000	37	0.0900	0.0360	0.0590
	350	350,000	37	0.0973	0.0308	0.0505
	400	400,000	37	0.1040	0.0270	0.0442
	500	500,000	37	0.1162	0.0216	0.0354
	600	600,000	61	0.0992	0.0180	0.0295
	700	700,000	61	0.1071	0.0154	0.0253
	750	750,000	61	0.1109	0.0144	0.0236
	800	800,000	61	0.1145	0.0135	0.0221
	900	900,000	61	0.1215	0.0120	0.0197
	1000	1,000,000	61	0.1280	0.0101	0.0177

D. Examine your conductors for types of insulation. Record the type letter below.

1.

2.

3.

4.

5.

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LAB SHEET #1

E. Show your results to your instructor.

F. Put up your equipment.

BASICS OF POWER DISTRIBUTION

UNIT I
TEST

NAME____ SCORE______________

1. Match the terms associated with basics of power distribution to their correct definitions. Place the correct number in the blank.

_____a. A set of minimum standards for electrical installation developed by the National Fire Protection Association (NFPA) and updated every three years.

_____b. Assemblies of overcurrent device contained in a cabinet.

_____c. Protection against overloads and short circuits is provided by fuses, circuit breakers and ground fault circuit interrupter (GECI).

_____d. A panelboard away from the service entrances.

_____e. Known as the switch box, pull box or main box.

_____f. Each utility company has its own requirement as to sevice entrance.

_____g. Used typically for high horsepower motor.

_____h. A set of conductors that extend beyond the last overcurrent device in a system.

_____i. A set of conductors that supply a group of travel circuits.

_____j. A device that detects small amounts of current leakage and interrupts the circuit when the leakage reaches a certain level.

_____k. Special application of the order of 2400, 4800, 4160, etc., are for exceptional purposes.

_____l. Used typically in low horsepower motor.

_____m. The conduction brought into the customer service entrance.

1. Panelboards
2. Feeder
3. Service entrance box
4. High-voltage distribution
5. Overcurrent protection
6. Branch circuit
7. 240 V three-phase distribution
8. 480 V three-phase distribution
9. Overhead and underground
10. Ground fault circuit interrupter
11. National Electric Code (NEC)
12. Subfeeders
13. Service drop
14. 277-480 V three-phase distribution

TEST

_____n. A four-wire system and primarily for lighting large industrial plants.

2. What is accessible wiring?

3. What is accessible equipment?

4. What is a pressure connector (solderless)?

5. What is meant by "dust-tight"?

6. What is meant by "explosion-proof application"?

7. What is meant by "service lateral"?

8. What is meant by a "motor-circuit switch"?

9. What is a Class I location?

10. What are Class II locations?

11. What are Class III locations?

TEST

12. STOP. Have your instructor evaluate your test. If you received a score of 80 percent or more, continue to the next unit. If additional study is required, ask your instructor about study requirements and possible retesting.

BASICS OF POWER DISTRIBUTION

UNIT I

ANSWERS TO ASSIGNMENT SHEET #1 - THE NATIONAL ELECTRIC CODE

1. What is meant by "accessible" wiring?

   Cabable of being renewed without damaging a structure.

2. What is meant by accessible equipment?

   Admitting close approach no guarded by locked doors.

3. What is a pressure connector?

   A device that establishes connection between two or more conductors or between one or more conductors and a terminal by means of mechanical pressure and without solder.

4. What is meant by "dust-tight"?

   So constructed that dust will not enter the enclosing case under specified test conditions.

5. What is meant by "explosion-proof apparatus"?

   Apparatus enclosed in a case that is capable of sustaining an explosion of specified gases or vapors surrounding the enclosure by sparks, flashes, or explosion of the gases or vapors within and which operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.

6. What is meant by "service lateral"?

   The underground service conductors between the street main, including any risers at the pole or other structure or from transformers, and the first point of connection to the service-entrance conductors in a terminal box or meter or other enclosure with adequate space inside or outside the building wall. The point of connection shall be considered to be the point of entrance of the service conductors into the building.

7. What is meant by a "motor-circuit switch"?

   A switch, rated in horsepower, capable of interrupting the maximum operating current of a motor of the same horsepower rating as the switch at the rated voltage.

BASICS OF POWER DISTRIBUTION

UNIT I

ANSWERS TO ASSIGNMENT SHEET #2 - THE NEC AND HAZARDOUS LOCATIONS

1. What is a Class 1 location?

   These are locations in which flammable gases or vapors are, or may be, present in the air in quantities sufficient to produce explosive or ignitible mixtures (NEC500-4).

2. What are Class II locations?

   These are locations which are hazardous because of the presence of combustible dust (see NEC500-5).

3. What are Class III locations?

   Easily ignitible fibers or materials producing combustible flyings are handled, manufactured, or used. (NEC500-6)

4. In Class I, Division 1 areas, what type of wiring must be used? (NEC501-4)

   Threaded rigid metal conduit, threaded steel intermediate metal conduit, or Type MI cable. (NEC501-4)

5. In class I areas, why is sealing needed in conduit systems and not in Type MI cable systems?

   Seals are provided in conduit systems to prevent the passage of gases, vapors, or fumes from one portion of the electrical system to another through the conduit. Type Mi cable is inherently prevented by construction of the cable. (NEC501-5)

6. Do Class I locations need to be grounded? (NEC501-16)

   Wiring and equipment in Class I locations are required to be grounded. Locknuts and bushings are not adequate grounding; they must have bonding jumpers around them. Where flexible conduit is used as permitted, bonding jumpers must be installed in parallel with each conduit. (NEC501-16)

ANSWERS TO ASSIGNMENT SHEET #2

7. Name some of the precautions that must be taken when transformers are used in Class II, Division 1 location?

   Transformers containing a flammable liquid shall be installed only in approved vaults which are so constructed that a fire cannot be communicated to the hazardous area. Transformers that do not contain a liquid that will burn must also be installed in vaults or must be enclosed in tight metal housings without ventilation. (NEC502-2)

8. Is grounding and bonding necessary in Class II locations?

   Wiring and equipment in Class II location shall be grounded. Locknuts and bushings are not adequate grounding; they must use bonding jumpers. (NEC502-16)

9. In class III, Division I locations, what type of wiring is required?

   Rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, or Types MI, MC, and SNM boxes and fittings must have tight-fitting covers. There must not be any screw-mounting holes within the box through which sparks might escape. (NEC503-3)

10. Commercial garages may use what kind of material for wiring?

    Rigid metal conduit, threaded steel intermediate metal conduit or Type MI, MC, or SNM cable. (NEC511-5)

11. What type of wiring is required in all aircraft hanger locations?

    The wiring must be in accordance with Class I, Division 1 locations. (NEC513-3)

12. Are these restrictions on switching circuits leading to or going through a gasoline-dispensing pump?

    The switches or circuits breakers in these circuits must be able to simultaneously disconnect all conductors of the circuit, including the grounded neutral, if any. (NEC514-5)

13. What is a Critical Branch?

    Critical Branch - A sub-system of an emergency system consisting of feeders and branch circuits supplying energy to task illumination and selected receptacles serving areas and functions related to patient care, and which can be connected to alternate power sources by one of more transfers switches. (NEC517-2)

BASICS OF POWER DISTRIBUTION

UNIT I

TEST ANSWERS

1. a. 11
   b. 4
   c. 5
   d. 12
   e. 3
   f. 9
   g. 8
   h. 6
   i. 2
   j. 10
   j. 10
   k. 4
   l. 7
   m. 13
   n. 14

2. Readily available to inspection, repair, removal, etc., without disturbing the building structure or finish. Not permanently closed by structure or finish of buildings.

3. May be readily reached without climbing over obstacles, not in locked or other hard-to-get-at areas, e.g., panels in kitchen cupboards, which are mounted in or on the walls above washers and dryers or in closets or bathrooms. Service entrance equipment that can only be reached by going into a basement, behind a stairway, or some other hindrance would most certainly not be termed "accessible".

4. A device that establishes a good electrical connection between two or more conductors by some means of mechanical pressure. It is used in place of soldering connections and should be of the approved type.

5. Being capable of keepi[illegible]ust out of the enclosed case so that dust cannot interfere with normal operation. This is discussed further in connection with Articles 500 and 502 of the NEC, which both cover hazardous locations.

6. Apparatus enclosed in a case that is capable of sustaining an explosion that may occur within itself and is also capable of preventing ignition of specified gases or vapors surrounding the enclosure by sparks, flashes, or explosion of the gases or vapors within; it must also operate at a temperature that will not ignite any inflammable atmosphere or residue surrounding it. If an explosion does occur within the equipment, the gases are allowed to escape either by a ground joint or by threads, and the escaping gases are thereby cooled to a temperature low enough to inhibit the ignition of any external gases.

7. The underground service conductors between the street main, including any risers at the pole or other structure or from transformers, and the first point of connection to the service-entrance conductors in a terminal box. The point of connection is considered to be the point of entrance of the service conductors into the building.

TEST ANSWERS

8. A switch, rated in horsepower, that is capable of interrupting the maximum operating overload current of a motor of the same horsepower rating as the switch at the rated voltage.

9. These are locations in which flammable gases or vapors are, or may be, present in the air in quantities sufficient to produce explosive or ignitible mixtures (See NEC, Article 500-4).

10. Those which are hazardous because of the presence of combustible dust (see NEC, Article 500-5).

11. Locations which are hazardous because of the presence of easily ignitible fibers or flyings, but in which such fibers or flyings are **not** likely to be suspended in the air in quantities sufficient to produce ignitible mixtures (see NEC, Article 500-6).

POWER DISTRIBUTION

UNIT II

RACEWAYS AND CONDUCTORS

RACEWAYS AND CONDUCTORS

UNIT II

OBJECTIVE

After completing this unit, the student should be able to calculate the resistance and ampacity of single or multiple conductors taking into consideration temperature and voltage drop derating faction. This knowledge will be shown by completing assignment sheets and test with a minimum score of 80 percent.

SPECIFIC OBJECTIVE

After completing this unit, the student should be able to

1. Match terms associated with raceways and conductors to their correct definitions.
2. Calculate the resistance of a length of conductors of different diameter.
3. Calculate the resistance of a conductor affected by temperature.
4. Calculate the ampacity of a conductor considering temperature derating factor.
5. Calculate the ampacity of a conductor considering multiple conductors in a raceway.
6. Calculate the ampacity of a conductor considering voltage drop factors.

RACEWAYS AND CONDUCTORS

UNIT II

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure, information, and assignment sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information, text, and assignment sheets.

   F. Demonstrate resistance calculations.

   G. Demonstrate ampacity calculations.

   H. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheets.

   C. Take test.

RACEWAYS AND CONDUCTORS

UNIT II

INSTRUCTIONAL MATERIAL

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Information sheets.

  D. Assignment sheets.

  E. Test.

  F. Answers to assignment sheets.

  G. Answers to test.

II. References

  A. Graham, Kennard C., Industrial and Commercial Wiring, Chicago, IL, American Technical Society, 1963.

  B. Smith, Robert L., Electrical Wiring, Industrial, Albany, New York, Delmar Publishing, 1984.

  C. Lenk, John D., Handbook of Simplified Electrical Wiring Design, Englewood Cliffs, New Jersey, Prentice - Hall, 1975.

  D. Fardo and Prewit, Electrical Experimentation & Practical Applications, Indianapolis, IN, Howard W. Sams & Co., 1978.

  E. Patrick and Fardo, Experimenting with Industrial Electrical System, Indianapolis, IN, Howard W. Sams & Co., 1978.

  F. Patrick and Fardo, Electrical Power System Technology, Indianapolis, IN, Howard W. Sams, 1979.

G. Palmquist, Roland E., Questions and Answers for Electrician Examinations, Indianapolis, IN., Howard W. Sams, 1979.

III. Related Material

A. National Electric Code, Quincy, MA, National Fire Protection Association, 1983.

RACEWAYS AND CONDUCTORS

UNIT II

PROCEDURE SHEET

____	1.	Study	Information Sheet - Terms and Definitions.
____	2.	Study	Chapter 2, Raceways and Conductors in your text.
____	3.	Study	Information Sheet, Items II - VI.
____	4.	Complete	Assignment Sheet #1, Raceways and Conductors.
____	5.	Stop	Have your instructor evaluate Assignment Sheet #1. If your instructor is satisfied with your performance continue to Step 6; otherwise repeat Steps 2-5.
____	6.	Study	Chapter 2 in your text. Information Sheet Items II-VI and Assignment Sheet #1.
____	7.	Take	Raceways and Conductors test.

RACEWAYS AND CONDUCTORS

UNIT II

INFORMATION SHEET

I. Terms and Definitions

A. Raceway - enclosed channels for wiring.

B. Rigid conduct - raceway that looks like plumbing pipe and must be treated the same as plumber's pipe. The inside of conduit has a smooth finish in order for conductors to be pulled through. This type is extremely strong and may be buried in concrete.

C. Electrical metallic tubing (EMT) - not as strong as rigid conduit and cannot be threaded but instead is secured by compression rings and/or set screws. It can be buried in concrete but not used around continuous moisture.

D. Metal-clad cable - sold with conductor installed inside of metal shield that is specially wound around the conductor. This type cannot be buried in concrete.

E. Nonmetallic cable - the plastic out shield encloses the conductor and in many cases will not meet local codes as the cable will not withstand abuse.

F. Wireways - metal channels with removeable panels inside which are placed conductors or bus bars.

G. Resistivity - the resistance of a specific conductor of a given cross-sectional area and length.

H. Circular mil - the unit of resistivity of a circular conductor. 1c mil = a circle of 0.001 inches in diameter. NOTE: to find the area of a round conductor simply square the diameter. ex. d=0.050 C mils = square mils × 1.273; A = 50x50 = 2500 mils OR ex. for a bus bar 1/4 in x 2 in; 1/4 in = 250 units; 2 in = 2000 units; 250 units x 2000 units = 500,000 square units - C mils = 500,000 x 1.273 = 636,500

I. Conductor sizes - a system of measuring conductor sizes called AWG (American Wire Gage). Conductors vary in sizes from the smallest No. 40 AWG to No. 0000 AWG. 40 AWG has d = 3.145 mils; 0000 AWG has d = 1/2 in = 460 miles (NOTE: wires larger than 0000 AWG are discribed in C mil sizes ex. 250 MCM = 250,000 C mils, = 500 mils, = 1/2 inches.)

J. Skin effect - for AC, current tends to flow on the outside of a conductor. This decreases the conductor area and increases the resistance (Ra $\frac{L}{A}$). From a practical point, this effect is a problem only on large conductors.

INFORMATION SHEET

K. Insulating materials - conductors must have some kind of insulation. NEC has six types: 600,1000, 2000, 3000, 4000, and 5000 V. The first two numbers are stamped on the conductor.

L. Insulation classifications - (include combination of the following)
R - rubber
T - thermoplastic
N - nylon
H - heat resistant
W - moisture resistant

example: THWN - heat and moisture resistant thermoplastic with nylon covering.

M. Ampacity - capacity in amps that a conductor can carry safely (see figure 21-10, page 42). Ampacity of three or less conductors in a cable or raceway.

N. Temperature derating factor - when temperatures are over 30° C, the ampacity of a conductor must be derated (figure 2-11, page 43).

O. Multiple conductor derating factor - when many conductors are used in a raceway (see figure 2-12, page 45). example: for No. 8AWG copper, single conductor is 55A. With R,T,TW insulation, the ampacity is reduced if it is used with 7 other conductors in a raceway to 38.5 A. .7x55 = 38.5

P. Three-phase derating factors - for a four-wire system, one conductor is a ground and doesn't carry current therefore the three conductors (figure 1) would apply here.

Q. Conductor voltage drop - there will be a voltage drop in a length of conductor due to heat loss. NEC permits 3% drop to the farthest outlet and a 5% drop if feeders are included.

II. Resistivity of a conductor

$$R = r \frac{L}{d^2}$$

R = resistance of a wire
r = specific resistance of a material
L = length in feet
d = diameter in units
A = area in units

example: Find the resistance of 1000 ft aluminum with d = 0.050 in at 20° C, using figure 2-5, page 33

$$R = \frac{17 \times 1000}{50^2} = \frac{17{,}000}{2{,}500} = \frac{6.8\ \Omega}{\text{ft}}$$

INFORMATION SHEET

III. Conductor resistance affected by temperatures

$$R_1 = R_2 \left(\frac{IZR+T_1}{IZR+T_2} \right) \qquad R_2 = R_1 \left(\frac{IZR+T_2}{IZR+T_1} \right)$$

R_1 = resistance at low temperature

$$R_1 = R_2 \frac{IZR + T_1}{IZR + T_2} \qquad R_2 = R_1 \frac{IZR + T_2}{IZR + T_1}$$

R_1 = resistance at low temperature

R_2 = resistance at high temperature

T_1 = low temperature

T_2 = high temperature

IZR = inferred zero resistance temperature

Inferred temperature for zero resistance (C°)	Material
-243	Silver
-234.5	Copper
-236	Aluminum
-202	Tungsten
-147	Nickel
-180	Iron
-6250	Nichrome

Example: Find the resistance of aluminum wire No. 16 at 60° C. Using figure 2-6, Page 36, give a value of 6.72 Ω

	Size (AWG or MCM)	Area	Number of wires	Diameter each wire	Dc resistance at 25°C (77°F) (Ω/1000 feet)	
					Copper	Aluminum
AWG	18	1,620	Solid	0.0403	6.51	10.7
	16	2,580	Solid	0.0508	4.10	6.72
	14	4,110	Solid	0.0641	2.57	4.22
	12	6,530	Solid	0.0808	1.62	2.66
	10	10,380	Solid	0.1019	1.018	1.67
	8	16,510	Solid	0.1285	0.6404	1.05
	6	26,240	7	0.0612	0.410	0.674
	4	41,740	7	0.0772	0.259	0.424
	3	52,620	7	0.0867	0.205	0.336
	2	66,360	7	0.0974	0.162	0.266
	1	83,690	19	0.0664	0.129	0.211
	0	105,600	19	0.0745	0.102	0.168
	00	133,100	19	0.0837	0.0811	0.133
	000	167,800	19	0.0940	0.0642	0.105
	0000	211,600	19	0.1055	0.0509	0.0836
MCM	250	250,000	37	0.0822	0.0431	0.0708
	300	300,000	37	0.0900	0.0360	0.0590
	350	350,000	37	0.0973	0.0308	0.0505
	400	400,000	37	0.1040	0.0270	0.0442
	500	500,000	37	0.1162	0.0216	0.0354
	600	600,000	61	0.0992	0.0180	0.0295
	700	700,000	61	0.1071	0.0154	0.0253
	750	750,000	61	0.1109	0.0144	0.0236
	800	800,000	61	0.1145	0.0135	0.0221
	900	900,000	61	0.1215	0.0120	0.0197
	1000	1,000,000	61	0.1280	0.0108	0.0177

at 25° C. Therefore,

$$R_2 = 6.72 \quad \left(\frac{-236+600}{-236+25^{\circ}\ C} \right)$$

$$F_2 = 7.62\ \Omega$$

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INFORMATION SHEET

IV. Temperature derating

Example: take a system that requires 115A and with three copper TW conductors to be operated at 45° C. What size of conductors should be used ?

Use figure 2-11 and 1.41

1.41x115 = 116.15A

Then look in figure 2-10. No. 1 AWG is too small for the 116A. Chose the next largest size which would be No. 0 AWG.

V. Multiple conductor derating

To find the ampacity of a single conductor in a raceway with more than three multiple the single ampacity by the derating factor.

Example: for No. 8 AWG R, T or TW the ampacity is 55A for a single conductor (see fig 2-9, page 41).

	Size	Copper		Aluminum	
	AWG or MCM	R,T,TW, 60° C(140° F)	RH, RHW, TH THWN, THW 75° C(167° F)	R,T,TW 60° C(140° F)	RHW, TH THW, THWN 75° C(167° F)
AWG	14	20	20	—	—
	12	25	25	20	20
	10	40	40	30	30
	8	55	65	45	55
	6	80	95	60	75
	4	105	125	80	100
	3	120	145	95	115
	2	140	170	110	135
	1	165	195	130	155
	0	195	230	150	180
	00	225	265	175	210
	000	260	310	200	240
	0000	300	360	230	280
MCM	250	340	405	265	315
	300	375	445	290	350
	350	420	505	330	395
	400	455	545	355	425
	500	515	620	405	485
	600	575	690	455	545
	700	630	755	500	595
	750	655	785	515	620
	800	680	815	535	645
	900	730	870	580	700
	1000	780	935	625	750

Then, if this conductor is operated in a raceway with 4 to 6, other conductors use the derating factor of .8 from fig 2-12, page 15, to give: .8x55 = 44.0 A

VI. Conductor voltage drop.

Example: assuming a resistivity of 17 for aluminum what size conductors are required to supply a 100A load 300 ft from a 120 V source with a voltage drop not to exceed 3%?

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INFORMATION SHEET

$$C\ \text{mil} = \frac{17 \times 100 \times (300 \times 2)}{120 \times 0.03}$$

$$= 283333 \text{ or } 284\ \text{MCM}$$

From fig 2-6, page 36, the next largest size is 300 MCM. Then checking figure 2-10, shows that 300 MCM has an ampacity of 190 which is much larger than 100A. (NOTE: Be sure to consider derating factors if necessary.)

RACEWAYS AND CONDUCTORS

UNIT II

ASSIGNMENT SHEET #1 - RACEWAYS AND CONDUCTORS

1. Find the resistance of 500 ft of aluminum conductor with $d = 0.025$ at 20° C.

2. Find the resistance of copper wire No. 14 AWG at 50° C.

3. What size conductor should be used in a system that requires 100A and has 3 copper TW conductors operated at 40° C.

4. Find the ampacity of a single No. 3 AWG TW conductor that is operated in a raceway with 8 other conductors.

5. Determine the size of copper conductor required to supply a 80 A load 50 ft from a 120 V source with a voltage drop not to exceed 4%.

RACEWAYS AND CONDUCTORS

UNIT II

TEST

NAME____SCORE____________

This is an open book test.

1. Match terms associated with raceways and conductors to their correct definitions. Place the correct number in the blank.

_____a. For AC, current tends to flow on the outside of a conductor.

_____b. The resistance of a specific conductor of a given cross-sectional area and length.

_____c. The unit of resistivity of a circular conductor.

_____d. A system of measuring conductor sizes called AWG.

_____e. The plastic out shield encloses the conductor and in many cases will not meet local codes as the cable will not withstand abuse.

_____f. Metal channels with removeable panels inside which are placed conductors or bus bars.

_____g. Enclosed channels for wiring.

_____h. Raceway that looks like plumbing pipe and must be treated the same as plumber's pipe.

_____i. Not as strong as rigid conduit and cannot be threaded but instead is secured by compression rings and/or set screws.

_____j. Sold with conductor installed inside of metal shield that is specially would around the conductor.

_____k. R(rubber), T(thermoplastic, N(nylon), H(heat resistant, W(moisture resist.)

_____l. For a four-wire system, conductor is a ground and doesn't carry current therefore the three conductors would apply here.

1. Insulating Material
2. Ampacity
3. Multiple conductor derating factor
4. Conductor voltage drop
5. Three-phase derating factors
6. Temperature derating factor
7. Insulation classifications
8. Raceway
9. Skin effect
10. Conductor sizes
11. Rigid conduct
12. Circular mil
13. Electrical metallic tubing (EMT)
14. Resistivity
15. Metal-clad cable
16. Wireways
17. Nonmetallic cable

TEST

_____m. Conductors must have some kind of insulation. NEC has six types.

_____n. There will be a voltage drop in a length of conductor due to heat loss.

_____o. When temperatures are over 30° C, the ampacity of a conductor must be derated.

_____p. Capacity in amps that a conductor can carry safely.

_____q. When many conductors are used in a raceway.

2. Find the resistance of 1000 ft of aluminum conductor with d = 0.060 at 20° C.

3. Find the resistance of aluminum wire No. 8 AWG at 70° C.

4. What size conductor should be used in a system that requires 90A and has 3 copper RH conductors operated at 50° C?

TEST

5. Find the ampacity of a single No 6 AWG TH conductor that is operated in a raceway with 4 other conductors.

6. Determine the size of copper conductors required to supply a 105A load 30 ft from a 120 V source with a voltage drop not to exceed 3%.

7. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

RACEWAYS AND CONDUCTORS

UNIT II

ASSIGNMENT SHEET #1 - ANSWERS

1. $R = \frac{17 \times 500}{25^2} = 13.6\ \Omega$

2. $R_2 = 2.57 \left(\frac{235^\circ + 50^\circ}{235^\circ + 25^\circ}\right) = 2.82\ \Omega$

3. Fig 2 gives a temperature factor of 1.22. Which gives 1.22x100 = 122

   Then using figure 1 shows that No. OAWG will be sufficient for this application.

4. Using figure 6 gives an ampacity of 120. But due to the fact the conductor is in a raceway with over seven other conductors, use figure 3 to give 0.7; then 0.7 x 120 = $\underline{84A}$

5. Figure 4 gives a resistivity of copper of 104.

$$C\ mil = \frac{104 \times 80 \times (60 \times 2)}{120 \times 0.04}$$

$$= 208{,}000 \text{ or } 208\ MCM$$

   The next largest is 250 MCM. checking figure 1 shows that for all types of insulation, this size will work.

RACEWAYS AND CONDUCTORS

UNIT II

TEST ANSWERS

1. a. 9
   b. 14
   c. 12
   d. 10
   e. 17
   f. 16
   g. 8
   h. 11
   i. 13
   j. 15
   k. 7
   l. 5
   m. 1
   n. 4
   o. 6
   p. 2
   q. 3

2. $R = \dfrac{17 \times 1000}{60^2} = 4.7\ \Omega$

3. $R_2 = 1.05 \left(\dfrac{236 + 70}{236 + 25} \right)$

   $= 1.23\ \Omega$

4. Using 1.33 from fig 2-11 gives 1.33 x 90 = 119.7A.
   Conductor size No. 1 AWG will be sufficient.

5. Ampacity is 95A and derating factor of 0.8 is used to give .8 x 95 = 76A

6. $C\ mil = \dfrac{17 \times 105 \times (30 \times 2)}{120 \times 0.03}$

   $= 29{,}790$ AWG

   The next largest is No. 4 AWG, but No. 4 has an ampacity of 70A which is not high enough; therefore choose No. 1 AWG with an ampacity of 110A.

POWER DISTRIBUTION

UNIT III

FEEDERS AND BRANCHES

FEEDERS AND BRANCHES

UNIT III

OBJECTIVE

After completing this unit, the student should be able to use the National Electric Code to answer feeder and branch questions, calculate ampacity in branch and feeder circuits and determine sizes of overcurrent protection devices. This knowledge will be shown by completing assignment sheets, lab sheets and test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Use the National Electric Code to answer questions.
2. Calculate ampacity from service entrance to feeders.
3. Calculate voltage drops for single and multiple feeders.
4. Calculate the voltage drops in a branch circuit with more than one outlet.
5. Calculate the size of overcurrent protection devices.
6. Demonstrate the ability to
    a. Wire power distribution panels
    b. Wire branch circuits from a power panel

FEEDER AND BRANCHES

UNIT III

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure, information, assignment, and lab sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information, assignment, and lab sheets.

   F. Demonstrate using the Code to find answers.

   G. Demonstrate calculating ampacities and voltage drops.

   H. Demonstrate various overcurrent protection devices.

   I. Assist students in wiring power panels and branch circuits.

   J. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheets.

   C. Take test.

FEEDERS AND BRANCHES

UNIT I

INSTRUCTIONAL MATERIAL

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Information sheets.

  D. Assignment sheets.

  E. Lab sheets.

  F. Test.

  G. Answers to assignment sheets.

  H. Answers to test.

II. References

  A. Graham, Kennard C., Industrial and Commercial Wiring, Chicago, IL, American Technical Society, 1963.

  B. Smith, Robert L., Electrical Wiring, Industrial, Albany, New York, Delmar Publishing, 1984.

  C. Lenk, John D., Handbook of Simplified Electrical Wiring Design, Englewood Cliffs, New Jersey, Prenticc - Hall, 1975.

  D. Fardo and Prewit, Electrical Experimentation & Practical Applications, Indianapolis, IN, Howard W. Sams & Co., 1978.

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  F. Patrick and Fardo, Electrical Power System Technology, Indianapolis, IN, Howard W. Sams, 1979.

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G. Palmquist, Roland E., *Questions and Answers for Electrician Examinations*, Indianapolis, IN., Howard W. Sams, 1979.

III. Related Material

A. National Electric Code, Quincy, MA, National Fire Protection Association, 1983.

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FEEDERS AND BRANCHES

UNIT III

PROCEDURE SHEET

_____1. Study — Chapter 3, Feeders, Branch Circuits and Overcurrent Protection.

_____2. Complete — Assignment Sheet #1.

_____3. Stop — Have your instructor evaluate Assignment Sheet #1. If your instructor is satisfied with your performance proceed to Step 4. Otherwise, repeat Steps 1-3.

_____4. Complete — Assignment Sheet #2.

_____5. Stop — Have your instructor evaluate Assignment Sheet #2. If your instructor is satisfied with your performance proceed to Step 6. Otherwise, repeat Steps 1, 4 and 5.

_____6. Complete — Lab Sheet #1.

_____7. Stop — Have your instructor observe the results of your experiment. If the instructor is satisfied proceed to Step 8. Otherwise, repeat Steps 6 and 7.

_____8. Study — Chaper 3, Assignment Sheets #1 and #2, and your lab sheet.

_____9. Take — Feeder, Branch Circuit, and Overcurrent Protection test.

FEEDERS AND BRANCHES

UNIT III

ASSIGNMENT SHEET #1 - FEEDER, BRANCH CIRCUIT AND OVERCURRENT PROTECTION QUESTIONS

Use your NEC text to answer the following questions:

1. What are voltages according to the National Electric Code?

2. What material is commonly used when referring to conductors? (NEC110-5)

3. Name several ways conductors may be spliced or joined together? (NEC110-14)

4. Can wire color coded green be used for circuit wires? (NEC210-5)

5. Is the smallest sized wire permissible for a feeder circuit number 10 wire? (NEC215-2)

6. Can one use demand factors in determining feeder loads? (NEC220-11)

ASSIGNMENT #1

7. For all but general illumination, what loads are used in figuring outlets? (NEC220-2)

8. What is the maximum rating that would be permitted on a fixed appliance located on a 10- amp branch circuit on which there is a lighting fixture? (NEC210-23)

9. On feeder and branch circuits, what are the permissible voltage drops allowable? (NEC215-2)

10. Is there an exception to the ruling of 150 volts maximum between conductors?(NEC210-6)

11. Is there a minimum size for branch-circuit conductors? (NEC210-19)

12. What soldering precautions must be used? (NEC110-14)

13. Can the same demand factors be used on electric clothes dryer loads as they are used on electric ranges. (NEC220-18)

FEEDERS AND BRANCHES

UNIT III

ASSIGNMENT SHEET #2 - FEEDER, BRANCH CIRCUIT AND OVERCURRENT PROTECTION PROBLEMS

1. Calculate the ampacity for the service entrance equipment for the following single-family residence supplied with 120 V.

   $A = 2000\ ft^2$
   5 kw electric dryer
   1.5 kw dish washer
   3.5 kw small appliance

2. Calculate the voltage drop for a 40 kw load having 115/230 V copper THW service and a distance of 80 ft.

ASSIGNMENT SHEET #2

3. Calculate the voltage drop for a 45 kw load divided equally between three locations having 113/230 V copper THW service and distances of 125 ft, 75 ft and 50 ft. A switchboard provides service to the three branches and is 50 ft from the service entrance.

4. If a load is continuous in a branch circuit by what percent must the maximum be derated? Give an example.

5. Calculate the voltage drop for a branch circuit where a 20A panel is used and 3 outlets are located at distances of 15 feet apart. Each outlet has a load of 4A. Use 14 AWG copper conductor.

ASSIGNMENT SHEET #2

6. If the number of taps on a branch circuit is 6 or less but never more than 8 and the voltage source is 115 V in order stay with in voltage drop guidelines, keep the branch circuit length to the final outlet.

   a. ____________ ft if the final outlet carries more than 80 percent of the maximum rated load.

   b. ____________ ft if the final outlet carries between 50 and 80 percent of the maximum rated load.

   c. ____________ ft if the find outlet carries up to 50 percent of this maximum rated load.

FEEDERS AND BRANCHES

UNIT III

LAB SHEET #1 - WIRING POWER DISTRIBUTION PANELS

I. Equipment

A. 1-American wire gauge
B. 1-Power distribution panel (100 amp, 1 ϕ, 3 wire)
C. 2 ft - 14-2 WG nonmetallic swathed cable
D. 1-Knife
E. 1-Box connectors
F. 1-Screwdriver
G. 1-Needle nose pliers
H. VOM
I. 240 VA power source

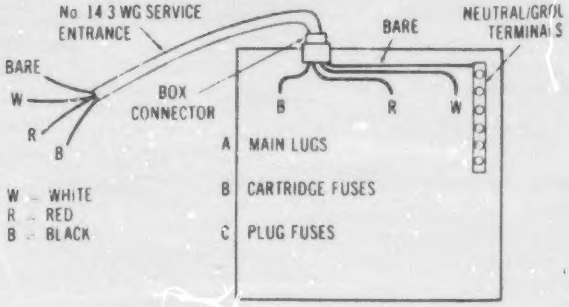
II. Procedure

A. Remove 8 inches of outer insulation from the 14-3 WG cable.

B. Check the size of the wires using the AWG ______________

C. Bring the cable into the panel box (shown in Figure 1) through a box connector until 1½ inches of the insulation is inside the box.

FIGURE 1


No. 14 3 WG SERVICE ENTRANCE
BARE
NEUTRAL/GROU TERMINALS
BARE
W
R
B
BOX CONNECTOR
B
R
W
A MAIN LUGS
B CARTRIDGE FUSES
C PLUG FUSES
W = WHITE
R = RED
B = BLACK

LAB SHEET #1

D. Tighten the screws on the box connector to clamp the cable in place.

E. Check for continuity by using the VOM and placing the probe at point A of Figure 1 and the other probe at point C.

F. Also check the continuity of the neutral/ground terminals in the box.

G. Now connect the red and black wires of the service entrance cable to the main lugs. Each main lug is to be connected.

H. Connect the ground and white wires to the neutral/ground terminals.

I. Strip the other ends of the 14-3 cable for connection to a 240 VAC power source.

J. Have your instructor check your wiring.

K. Next connect the 14-3 cable to the 240 VAC source.

L. Turn on the VAC carefully.

M. Using the VOM meter to measure and record the voltage readings (use Figure 2 and table)

TABLE:

(1) E_{AB} = ______ volts

(2) E_{AC} = ______ volts

(3) E_{AD} = ______ volts

(4) E_{AE} = ______ volts

(5) E_{BC} = ______ volts

(6) E_{CD} = ______ volts

(7) E_{DE} = ______ volts

(8) E_{BD} = ______ volts

(9) E_{CE} = ______ volts

(10) E_{AF} = ______ volts

(11) E_{AG} = ______ volts

(12) E_{AH} = ______ volts

(13) E_{AI} = ______ volts

(14) E_{AJ} = ______ volts

(15) E_{AK} = ______ volts

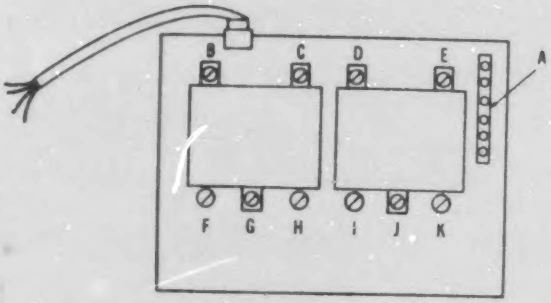
(16) E_{FH} = ______ volts

(17) E_{IK} = ______ volts

(18) E_{GJ} = ______ volts

LAB SHEET #1

FIGURE 2


B
C
D
E
A
F
G
H
I
J
K

N. Make a schematic sketch of the power distribution panel.

LAB SHEET #1

O. Have your instructor review your work.

P. Disconnect the power panel from the power source.

Q. Do not unwire the power panel, as it will be used in the next experiment.

R. Put your equipment away.

FEEDERS AND BRANCHES

UNIT III

LAB SHEET #2 - WIRING BRANCH CIRCUITS FROM A POWER DISTRIBUTION PANEL

I. Equipment

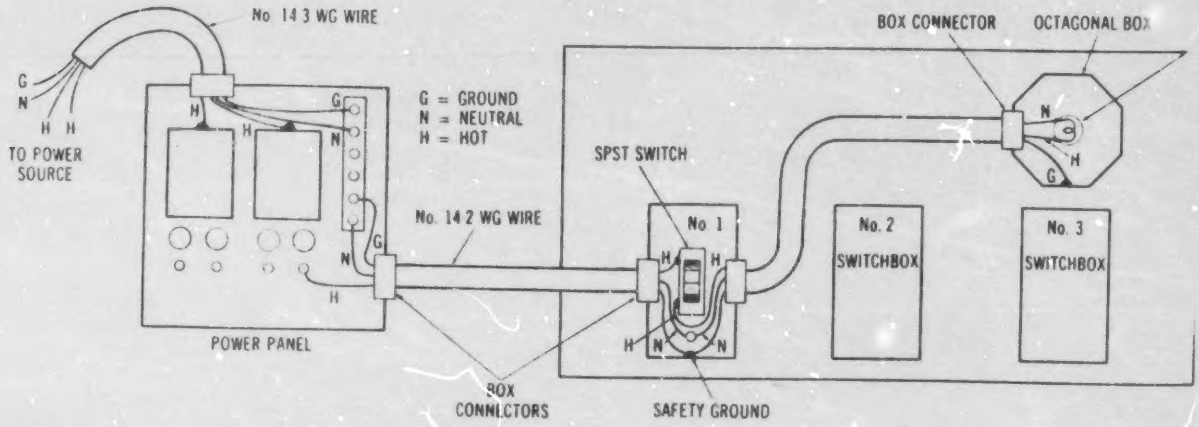
A. 1-Metal switch box
B. 1-SPST switch
C. 1-Wired power panel
D. 1-Lamp receptacle
E. 1-Lamp
F. 4-Box connectors
G. Solderless connectors
H. 14-2 WG wire
I. 14-3 WG wire
J. Needle
K. Screwdriver
L. Knife
M. VOM

II. Procedure

A. Use the power panel prepared in Lab Sheet #1. Be sure the 240 VAC power source is off.

B. Run a 120 V. 14-2 WG cable from one of the plug fuse terminals and the neutral/ground terminals to a metal switch box as shown in Figure 1.

FIGURE 1


No. 14 3 WG WIRE
G
N
H H
TO POWER SOURCE
G = GROUND
N = NEUTRAL
H = HOT
H
H
G
N
G
N
H
POWER PANEL
No. 14 2 WG WIRE
SPST SWITCH
No 1
H
H
H
N
N
BOX CONNECTOR
OCTAGONAL BOX
N
H
G
No. 2 SWITCHBOX
No. 3 SWITCHBOX
BOX CONNECTORS
SAFETY GROUND

LAB SHEET #2

C. Secure both ends with box connectors.

D. Strip 1/2 inch insulation from one end of the cable.

E. Connect the striped end of the cable to the terminal strips. (NOTE: Black to five terminal - White to neutral/ground terminals)

F. Take a SPST switch and use the VOM to check for continuity both before and after throwing the SPST switch.

G. Run a 14-7 WG cable from the switch box to the lamp receptacle connecting both ends with box connectors.

H. Prepare the cable by striping off the ends.

I. Now make the connection as shown in Figure 1 between the switch and the lamp receptacle.

J. Now check for continuity by placing the VOM back across the light terminals. What happens?

____

____

Screw in the lamp.

K. Connect the power panel to the 240 VAC power source.

L. Have your instructor check your wiring.

M. Turn on the power source.

N. Test your circuit by timing the SPST switch on and off.

O. Turn off the power source.

P. Review your set-up.

Q. Put up your equipment.

FEEDERS AND BRANCHES

UNIT III

TEST

NAME ____ SCORE __________

1. There are 2,500 square feet of floor area in a house which contains an electric range rated at 12 kw and an electric dryer rated at 4,500 watts. Calculate: (a) the general lighting load; (b) the minimum number and sizes of branch circuits required; (c) the minimum size of feeders (service conductors) required.

   (NOTE: Use the National Electric Code to solve problems:

   Tables 220-11
   220-13
   220-18
   220-19
   220-20)

TEST

2. Calculate the voltage drop for a 30 kw load that is divided into three aluminum loads of 18 kw, 8 kw and 10 kw. These loads are 100 ft, 250 ft, and 200 ft, respectively, from a switchboard that is 250 ft from the service entrance that is supplying 115/230 V. Also select appropriate overcurrent protection devices.

TEST

3. Use your text and/or the NEC to answer the following questions.

   a. According to the NEC, what are voltages?

   b. When referring to conductors, what material is referred to? (NEC110-5)

   c. How may conductors be spliced or joined together? (NEC110-14)

   d. Can green colored wire be used for circuit wires? (NEC210-5)

   e. What is the smallest size wire permissible for a feeder circuit? (NEC215-2)

   f. Are demand factors permitted in determining feeder loads? (NEC220-11)

   g. What loads are used in figuring outlets for other than general illumination? (NEC220-2)

   h. A fixed appliance is located on a 15- or 2-amp branch circuit on which there is a lighting fixture. What is the maximum rating that would be permitted on the fixed appliance? (NEC210-23)

   i. What are the permissible voltage drops allowable on feeders and branch circuits? (NEC215-2)

TEST

j. What are the exceptions to the ruling of 150 volts maximum between conductors? (NEC210-6)

k. What is the minimum size for branch-circuit conductors? (NEC210-19)

l. When soldering, what precautions must be used? (NEC110-14)

m. Can demand factors be used on electric clothes dryer loads in the same manner as they are used on electric ranges? (NEC220-18)

4. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue on to the next unit. If additional study is necessary, ask your instructor about additional study requirements and possible retest.

FEEDERS AND BRANCHES

UNIT III

ASSIGNMENT SHEET #1 - ANSWERS

1. The voltage considered shall be that at which the circuit operates.

2. To copper, unless otherwise specified. Where other materials are specified, the wire sizes must be changed accordingly.

3. They must be spliced or joined together by approved splicing devices or by brazing, welding, or soldering with a fusible metal or alloy.

4. No. Green is intended for identification of grounding conductors.

5. Yes.

6. Yes; they are given in NEC Section 220-11.

7. Outlets supplying specific loads and appliances must use the ampere rating of the appliance. Outlets supplying heavy-duty lampholders must use 600 volt-amperes; for other outlets, they must use 180 volt amperes.

8. In no case shall the load exceed the branch circuit rating.

9. On Feeders, not more than 3% for power, heating, and lighting loads or combinations thereof. A total maximum voltage drop not to exceed 5% for conductors and for combinations of feeders and branch circuits.

10. Yes, permanently connected appliances, portable appliances of more than 1,380 watts, and portable motor-operated appliances of 1/4 hp rating or greater.

11. Yes, they cannot be smaller than No. 8 for ranges of 8 3/4 kw or more rating and not smaller than No. 14 for other loads.

12. All joints or splices must be electrically and mechanically secure before soldering and then soldered with a noncorrosive flux. This does not apply to conductors for grounding purposes, soldering is not allowed on these conductors.

13. Yes, see Table 220-18.

FEEDERS AND BRANCHES

UNIT III

ASSIGNMENT SHEET # 2- ANSWERS

1. fixed load 5 kw
   1.5 kw

   6.5 kw

   reduced power demand

   lighting (2000 x 3 =) 6 kw
   small appliances 3.5 kw
   9.5 kw

   From figure 3-5 3.5 at 100% = 3.5 kw
   6 at 35% = 2.1 kw
   reduced power demand 5.6 kw

   therefore 6.5 kw
   + 5.6 kw
   12.1 kw

   the ampacity will be $\frac{12.1 \text{ kw}}{120 \text{ V}} = 100.8\text{A}$

2. Assume 1.7% voltage drop and required current of $\frac{40 \text{ kw}}{230 \text{ V}} = 174\text{A}$

   Then $\text{C mil} = \frac{104 \times 174 \times (80 \times 2)}{230 \times 0.017} = 740{,}501$

   = 741 MCM

   Next largest is 750 MCM which has a maximum ampacity of 475 and resistance of 0.0144/1000 ft gives 2.5 V which is well below 3.9 V.

3. The maximum voltage drop considering 2% is 4.6 V. The required currents are 15 kw/230 V = 66A and the current for the feeder is 198A.

   The wire size for each subfeeder:

   a. $\text{C mil} = \frac{104 \times 66 \times (125 \times 2)}{2}$

   = 858,000 or 900 MCM
   Resistance is 0.0120/1000 ft or 0.003Ω. The voltage drop is 0.003x66 = 0.198, well below 2%.

ASSIGNMENT SHEET # 2 - ANSWERS

b. $$\text{C mil} = \frac{104 \times 66 \times (75 \times 2)}{2} = 515 \text{ MCM}$$

Or 600 MCM

Resistance is 0.018/1000 ft or 0.00027Ω. The voltage drop is 0.178V.

c. $$\text{C mil} = \frac{104 \times 66\ (50 \times 2)}{2} = 344 \text{ MCM}$$

Or 400 MCM

Resistance is 0.027/1000 ft or 0.0022Ω. The voltage drop is 0.178 V.

Now the ampacity for the overcurrent devices (This device cannot have ampacity greater than the wire size but must have an ampacity equal to/or greater than the anticipated load (3x66 = 198A)

$$\text{Cmil} = \frac{104 \times 198 \times 50 \times 2}{2} = 1030 \text{ MCM}$$

Therefore switching to aluminum conductor provides:

$$\text{Cmil} = \frac{17 \times 198 \times 50 \times 2}{2} = 169 \text{ MCM}$$

OR No. 0000 AWG which will carry 180 A. So selecting the next largest or 250 MCM gives a resistance of 0.0708/1000 ft or 0.00708Ω. The voltage drop will be 1.4V. The largest voltage drop will be 1.4 + 0.198 = 1.598V or

$$\frac{1.598}{230} = 0.007 \text{ below } 2\%.$$

4. For continuous loads, the maximum must be derated to 80 percent. For example a 30A circuit is required for a 24A continuous load.

5. The voltage to the first panel is

$$V = \frac{(2 \times 15) \times 2.57 \times 12}{1000} = 0.93V$$

The drop to the next outlet is

$$\frac{(2 \times 15) \times 2.57 \times 8}{1000} = 0.62$$

ASSIGNMENT SHEET # 2 - ANSWERS

and to the last is

$$\frac{(2x15) \times 2.57 \times 4}{1000} = 0.31 \text{ V}$$

The total drop is 1.86 V

The maximum allowed is 3.45

6. a. less than 40
   b. less than 60
   c. less than 90

FEEDERS AND BRANCHES

UNIT III

TEST ANSWERS

1. (a) 2,500 sq. ft at 3 watts per sq. ft. equals 7,500 watts.

   (b) 7,500 watts divided by 115 volts equals 65 amperes; this would require a minimum of five 15-amp circuits with a minimum of No. 14 wire, or a minimum of four 20-amp circuits with a minimum of No. 12 wire.

Table 220-11. Lighting Load Feeder Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (volt-amperes)	Demand Factor Percent
Dwelling Units	First 3000 or less at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
*Hospitals	First 50,000 or less at	40
	Remainder over 50,000 at	20
*Hotels and Motels Including Apartment Houses without Provision for Cooking by Tenants	First 20,000 or less at	50
	From 20,001 to 100,000 at	40
	Remainder over 100,000 at	30
Warehouses (Storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All Others	Total Volt-amperes	100

* The demand factors of this table shall not apply to the computed load of feeders to areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Table 220-18
Demand Factors for Household Electric Clothes Dryers

Number of Dryers	Demand Factor Percent
1	100
2	100
3	100
4	100
5	80
6	70
7	65
8	60
9	55
10	50
11-13	45
14-19	40
20-24	35
25-29	32.5
30-34	30
35-39	27.5
40 & over	25

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TEST ANSWERS

Small appliance load:

A minimum of two small-appliance circuits (see NEC, Article 220-3b) of 1,500 watts each; these will require 20-amp 2-wire circuits with No. 12 wire.

A 12-kw range has a demand of 8 kw, according to Table 3. 8,000 watts divided by 230 volts equals 35 amps; therefore, a minimum of No. 8 wire with a 40-amp service would be required, although good practice would indicate the use of No. 6 wire with a 50-amp circuit breaker.

The dryer; 4,500 watts divided by 230 volts equals 20 amps; therefore, you would use No. 12 wire with a 20-amp circuit; however, good practice, with higher wattages coming all the time in dryers, would suggest No. 8 wire with a 40-amp circuit breaker. Laundry circuit, 1,500 watts.

Table 220-13
Demand Factors for Nondwelling Receptacle Loads

Portion of Receptacle Load to which demand factor applies (volt-amperes)	Demand Factor Percent
First 10 kVA or less	100
Remainder over 10 kVA at	5%

Table 220-19. Demand Loads for Household Electric Ranges, Wall-Mounted Ovens, Counter-Mounted Cooking Units, and Other Household Cooking Appliances over 1¾ kW Rating. Column A to be used in all cases except as otherwise permitted in Note 3 below.

NUMBER OF APPLIANCES	Maximum Demand (See Notes)	Demand Factors Percent (See Note 3)	
	COLUMN A (Not over 12 kW Rating)	COLUMN B (Less than 3½ kW Rating)	COLUMN C (3½ kW to 8¾ kW Rating)
1	8 kW	80%	80%
2	11 kW	75%	65%
3	14 kW	70%	55%
4	17 kW	66%	50%
5	20 kW	62%	45%
6	21 kW	59%	43%
7	22 kW	56%	40%
8	23 kW	53%	36%
9	24 kW	51%	35%
10	25 kW	49%	34%
11	26 kW	47%	32%
12	27 kW	45%	32%
13	28 kW	43%	32%
14	29 kW	41%	32%
15	30 kW	40%	32%
16	31 kW	39%	28%
17	32 kW	38%	28%
18	33 kW	37%	28%
19	34 kW	36%	28%
20	35 kW	35%	28%
21	36 kW	34%	26%
22	37 kW	33%	26%
23	38 kW	32%	26%
24	39 kW	31%	26%
25	40 kW	30%	26%
26-30	15 kW plus 1 kW for each range	30%	24%
31-40		30%	22%
41-50	25 kW plus ¾ kW for each range	30%	20%
51-60		30%	18%
61 & over		30%	16%

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TEST ANSWERS

(c) Minimum size of service.

General lighting	7,500 watts
Small appliance load	3,000 watts
Laundry circuit	1,500 watts
	12,000 watts
3,000 watts @ 100%	3,000 watts
9,000 watts @ 35%	3,150 watts
Net computer (without range and dryer)	6,150 watts
Ranger load	8,000 watts
Dryer load	4,500 watts
	12,500 watts
Net computed (with range and dryer)	8,650 watts

Loads of over 10 kw must have a minimum of 100-ampere service (see NEC, Article 250-94); therefore, the minimum service will be 100 amp. We can use No 1 TW wire or No. 3 RH wire, with a 100-ampere main disconnect. We must use a minimum of No. 6 service entrance ground wire with No. 1 entrance wire or a minimum of No. 8 service entrance ground wire with No. 3 entrance wire.

2. The required circuits are

12 kw/230 V = 53A
8 kw/230 V = 35A
10 kw/230 V = 44A

The wire sizes are

1. $\text{CMil} = \frac{17 \times 53 \times 100 \times 21}{2} = 90{,}100$

2. Which gives 0 AWG

$\text{CMil} = \frac{17 \times 35 \times (250 \times 2)}{2} = 148{,}750$

3. Which gives 000 AWG

$\text{CMil} \quad \frac{17 \times 44 \times (200 \times 2)}{2} = 149{,}600$

which gives 000 AWG

This will carry the respective loads. Each feeder will use 60A overcurrent protection devices.

Now the wire size for the feeder

$\text{CMil} = \frac{17 \times 132 \times (250 \times 2)}{2} = 561 \text{ MCM}$

TEST ANSWERS

which gives 600 MCM

This size will easily carry more amperage. With 0.014Ω X 32A = 1.95V.

The voltage drops for each feeder.

1. No.0 AWG has a resistance of 0.168Ω/1000 ft or 0.0336Ω. This gives for 53A: 1.78 V.
2. No. 000 AWG has a resistance of 0.105Ω/1000 ft or 0.0525Ω. This gives for 35A: 1.84 V.
3. No. 000 AWG gives 0.0407Ω. Which with 44A: 1.85 V.

Then for each total feeder:

1. 1.95+1.84 = 3.79 V. or 1.6%
2. 1.95+1.78 = 3.73 V less than 2%
3. 1.95+1.85 = 3.80 V less than 2%

3. a. Throughout this Code, the voltage considered shall be that at which the circuit operates.

   b. To copper, unless otherwise specified. Where other materials are to be used, the wire sizes must be changed accordingly.

   c. They must be spliced or joined together by approved splicing devices or by brazing, welding, or soldering with a fusible metal or alloy.

   d. No. Green is intended for identification of grounding conductors only.

   e. Number 10 wire.

   f. Yes; they are given in Table 2. Also, see NEC Section 220-11.

   g. Outlets supplying specific loads and appliances must use the ampere rating of the appliance. Outlets supplying heavy-duty lampholders must use 600 volt-amperes; for other outlets, they must use 180 volt amperes.

   h. 50% of the branch circuit rating.

   i. On feeders, not more than 3% for power, heating, and lighting loads or combinations thereof. A total maximum voltage drop not to exceed 5% for conductors and for combinations of feeders and branch circuits.

   j. Permanently connected appliances, portable appliances of more than 1,380 watts, and portable motor-operated appliances of 1/4 hp rating or greater.

TEST ANSWERS

k. They cannot be smaller than No. 8 for ranges of 8 3/4 kw or more rating and not smaller than No. 14 for other loads.

l. All joints or splices must be electrically and mechanically secure before soldering and then soldered with a noncorrosive flux. This does not apply to conductors for grounding purposes, soldering is not allowed on these conductors.

m. Yes, see Table 4.

POWER DISTRIBUTION

UNIT IV

GROUNDING

GROUNDING

UNIT IV

OBJECTIVE

After completing this unit, the student should be able to identify correct grounding and problem grounding and discuss correct policies as set forth in the National Electric Code. This knowledge will be shown by completing assignment sheets, lab sheets, and test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Complete statements pertaining to basic system and equipment grounding.
2. Discuss in writing, grounding requirements as set forth in the National Electric Code.

GROUNDING

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor
  A. Provide students with objective sheet.
  B. Provide students with procedure and assignment sheets.
  C. Make transparencies.
  D. Discuss unit and specific objectives.
  E. Discuss assignment sheets.
  F. Demonstrate grounding of basic systems and equipment.
  G. Summarize grounding requirements of the NEC.
  H. Give test.

II. Student
  A. Read objective sheet.
  B. Complete procedure sheets.
  C. Take test.

GROUNDING

UNIT IV

INSTRUCTIONAL MATERIAL

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheets.

  C. Assignment sheets.

  D. Test.

  E. Answers to assignment sheets.

  F. Answers to test.

II. References

  A. Graham, Kennard C., Industrial and Commercial Wiring, Chicago, IL, American Technical Society, 1963.

  B. Smith, Robert L., Electrical Wiring, Industrial, Albany, New York, Delmar Publishing, 1984.

  C. Lenk, John D., Handbook of Simplified Electrical Wiring Design, Englewood Cliffs, New Jersey, Prentice - Hall, 1975.

  D. Fardo and Prewit, Electrical Experimentation & Practical Applications, Indianapolis, IN, Howard W. Sams & Co., 1978.

  E. Patrick and Fardo, Experimenting with Industrial Electrical System, Indianapolis, IN, Howard W. Sams & Co., 1978.

  F. Patrick and Fardo, Electrical Power System Technology, Indianapolis, IN, Howard W. Sams, 1979.

G. Palmquist, Roland E., Questions and Answers for Electrician Examinations, Indianapolis, IN., Howard W. Sams, 1979.

III. Related Material

A. National Electric Code, Quincy, MA, National Fire Protection Association, 1983.

GROUNDING

UNIT IV

PROCEDURE SHEET

_____1. Study Chapter 4, Grounding Problems in Electrical Wiring.

_____2. Complete Assignment Sheet #1 - Checkout for Grounding Problems.

_____3. Stop Have your instructor evaluate Assignment Sheet #1. If the instructor is satisfied with your performance continue onto Step 4. Otherwise repeat Steps 1-3.

_____4. Answer Assignment Sheet #2 - Checkout for Grounding Problems using the NEC.

_____5. Stop Have your instructor evaluate Assignment Sheet #2. If your instructor is satisfied with your performance continue to Step 6. Otherwise repeat Steps 4 and 5.

_____6. Study Chapter 4 of your text and the assignment sheets.

_____7. Take Grounding Test.

GROUNDING

UNIT IV

ASSIGNMENT #1 - CHECKOUT FOR GROUNDING PROBLEMS

Use your text (Chapter 4) and/or the NEC to complete this assignment.

1. The NEC says that a system must be grounded if, after grounding,

   ____.

2. The NEC requires that electrical system grounds be made at

   __________________________________rather than at

   ____.

3. If, in a three-wire distribution, a conductor other than the neutral wire is connected to ground, what are the two NEC violations.

   a.

   b.

4. In a 3-phase, 4-wire distribution measuring from any ungrounded wire to ground gives ____________________________________.

5. If a three-phase, three-wire system is grounded, _________________

   ______________________________can be used for ground.

6. The NEC requires the system ground be made ______________________

   ____.

7. The NEC requirement that all equipment in an electrical system be grounded is called ____.

8. The NEC requires that all equipment be grounded to ______________.

9. The only equipment exempt from grounding is ______________________

   ____.

ASSIGNMENT SHEET #1

10. Fault current flows when ______________________________

____.

11. Fault current is used to ______________________________

____.

12. The practical method for grounding both a system and equipment is to ____.

13. The ground conductor is determined by the size of the

____.

14. If a ground conductor is copper No. 0 AWG, __________________

__________________________service conductor may be used.

15. The NEC requires that the neutral conductor not be grounded at any point beyond ______________________________________

Why?____

____.

16. Sketch the situation in problem #15 above.

17. The size of equipment grounding conductors is determined by

____

____.

ASSIGNMENT SHEET #1

18. Does a three-phase, three-wire system have to be grounded?

____

What has to be grounded? ______________________________.

19. In a 3-phase, 3-wire system, the service conductor is aluminum 350 MCM, what size does the equipment ground have to be if it is EMT?

____

____

____.

20. What could happen if raceway components are not making proper electrical contact (grounding)? ______________________________

____

____.

21. What are three problems that could be caused by raceway components not making proper electrical contact? ____________________

____

____.

22. In armored cable, what causes the low resistance of the cable?

____

____.

23. One of the simplest ground detectors is ____________________ connected in groups from each conductor to ground.

24. Ground detectors are often used on ____________________ which have metal surfaces readily accessible.

25. A "solid neutral" electrical system as required by the NEC means

____

26. The NEC also prohibits using a ____________________ in the grounded conductor unless there is a ____________________ on all conductors.

ASSIGNMENT SHEET #1

27. The Underwriter's Labs have adopted ______________________ as the temperature level at which Class A GCFI devices must operate.

28. Most GCFI are designed to operate on the ______________________ in the hot and neutral conductor.

29. Are GCFI circuit breakers independent of the equipment ground?

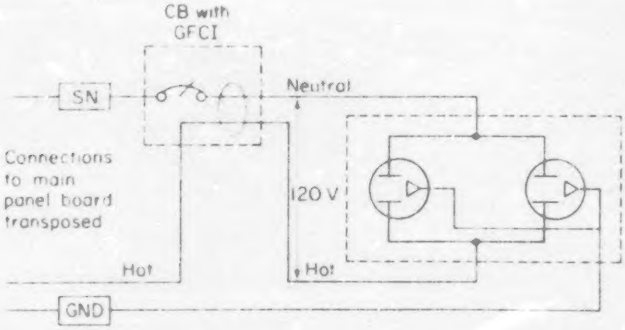
30. Are test circuits required by Underwriter's Lab?

31. List two ground faults that will trigger GCFI units.____________

____

____.

32. What is wrong with the installation of the GFCI in the following diagram?


CB with GFCI
SN
Neutral
Connections to main panel board transposed
120 V
Hot
Hot
GND

33. The general rule for GFCI use is ____________________________

____

____.

GROUNDING

UNIT IV

ASSIGNMENT SHEET #2 - QUESTIONS RELATING TO GROUNDING PROBLEMS

1. Must a neutral conductor be insulated to be buried in the ground in an underground service? (NEC230-30)

2. In a grounded service conductor, is it permissible to install overcurrent-protection devices? (NEC230-90b)

3. Can an overload device be used in a grounded conductor? NEC240-22) (NEC430-36)

4. What precautions must be taken if overload-device enclosures are mounted in damp locations? (NEC240-32)

5. Should AC circuits and systems be grounded? (NEC250-5)

6. Do circuits of 50 volts or less to ground have to be grounded? If they do, when do they have to be grounded? (NEC250-5a)

ASSIGNMENT SHEET #2

7. Must a grounded conductor be run to each service? (NEC250-23)

8. Is there an exception to grounding the noncurrent-carrying parts of portable tools and appliances? (NEC250-45)

9. A grounding electrod conductor is used for what reason?

10. How are corrections to service equipment to be made? (NEC250-72)

11. Is electrical continuity of metal raceways and metal-sheathed cable used on voltages exceeding 250 volts required? (NEC250-72)

12. Are pipe electrodes guided by requirements? (NEC250-83)

ASSIGNMENT SHEET #2

13. If grounding conductors may be spliced how far between splices? (NEC250-91)

14. What is the difference between using copper and alumium for grounding conductors? (NEC250-91a)

15. How are connections made to grounding conductor? (NEC250-113)

16. Is there anuthing that can be connected ahead of the service-entrance disconnecting switch? (NEC230-82)

17. Can service-entrance conductors be spliced? (NEC230-46)

18. Systems and circuits are grounded for what reason? (NEC250-1)

19. If a two-wire DC system has less than 300 volts between conductors, is it necessary to ground one wire? (NEC250-3)

20. Can a "made" grounding electrode be other than a driven pipe? (NEC250-83)

GROUNDING

UNIT IV

TEST

NAME____SCORE___________

1. The NEC says that a system must be grounded if, after grounding, ________________________ is less than _______________.

2. The NEC requires that electrical system grounds be made at __________ rather than at metal frames.

3. If, in a three-wire distribution, a conductor other than the neutral wire is connected to ground, what are the two NEC violations.

   a.

   b.

4. In a ____________________ distribution measuring from any ungrounded wire to ground gives 115 volts.

5. If a _____________________system is grounded, any of the conductors can be used for ground.

6. The NEC requires the system ground be made at the point of ___________ _________________________.

7. The NEC requirement that all equipment in an electrical system be grounded is called __________________________________.

8. The NEC requires that _______________be grounded to the same earth ground as the system ground.

9. The only equipment exempt from grounding is equipment that a person ____ ____.

TEST

10. ____________________ when a person in touch with earth ground touches a system that is accidentally in contact with ground.

11. Fault current is used to open ____________________.

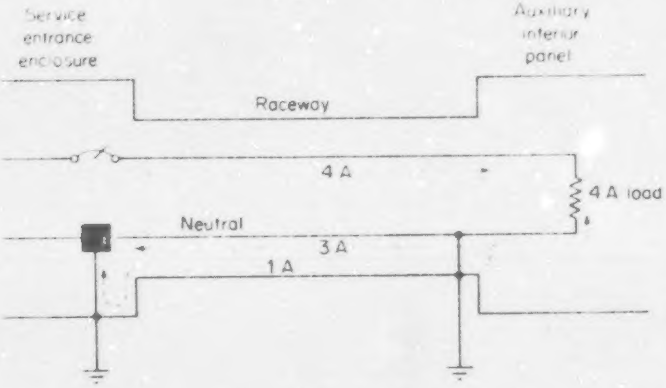
12. The practical method for grounding both ________________________ is to provide a common ground point in the service entrance.

13. The _______________ is determined by the size of the service conductor.

14. If a ground conductor is ____________________, 350 to 600 MCM service conductor may be used.

15. The NEC requires that the _________________ **not be ground**ed at any point beyond the service entrance, because current could flow back through the equipment.

16. Sketch the selection in problem #15 above.


Service entrance enclosure
Auxiliary interior panel
Raceway
4 A
4 A load
Neutral
3 A
1 A

17. The __________________________ of equipment grounding conductors is determined by the ___________ of the overcurrent device ahead of the equipment.

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TEST

18. A ______________________________ system does not have to be grounded--the ______________ does.

19. In a 3-phase, 3-wire system, the service conductor is ____________ _________________________. The size of the equipment ground if it is EMT is _____________________.

20. ___________________________ and ________________________ are possible if raceway components are not making proper electrical contact.

21. Shock hazard, arcing, and heating are three problems that could be caused by raceway components not ________________________________.

22. A ribbon of aluminum that runs the entire length of the cable causes _______________________ in armored cable.

23. ________ __________________ if one of the simplest ground detectors which is connected in groups from each conductor to ground.

24. ______________________ are often used on motors, machines and controllers which have metal surfaces readily accessible.

25. ___________________________ system as required by the NEC, means the grounded conductor must not be provided with an overcurrent device.

26. The NEC also prohibits using a switch in the ______________________ unless there is a switch on _______________________.

27. The Underwriter's Labs have adopted 5 milliamps as the ______________ ______________________ at which Class A GCFI devices must operate.

28. Most GCFI are designed to operate on the current inbalance in the ____.

TEST

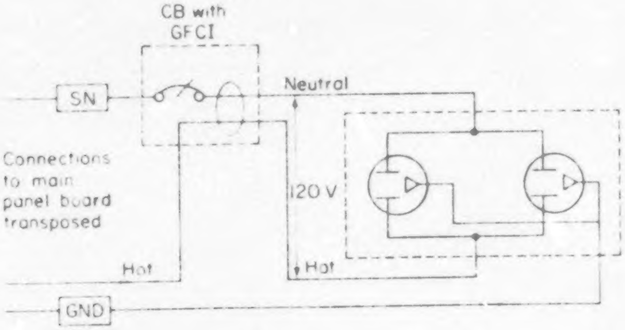
29. Yes/No ____________________. Are GCFI circuit breakers independent of the equipment ground?

30. Yes/No____________________. Are test circuits required by Underwriter's Lab?

31. Faulty appliance with equipment ground and ground fault on neutral conductors at the load side of the circuit breaker will trigger

__________________________________.

32. What is wrong with the installation of the GFCI in the following diagram?


CB with GFCI
Neutral
SN
Connections to main panel board transposed
120 V
Hot
Hot
GND

33. What is the general rule for GFCI use?

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TEST

34. Yes/No __________________. Can a bare neutral conductor be buried in the ground in an underground service? (NEC230-30)

35. True/False_________________. An overload device can be used in a grounded conductor where the overcurrent device simultaneously opens all conductors of the circuit.

36. Name three conditions when AC systems should be grounded.

    a.

    b.

    c.

37. Yes/No ___________________. If a grounded conductor is not going to be used in a building, must this grounded conductor be run to each service?

38. A grounding electrode conductor is used for _________________, ___________________, and __________________.

39. Electrical continuity of metal raceway or metal-sheathed cable shall be assured by ______________________ and ___________________________.

40. True/False _________________. Grounding conductors can be spliced.

41. True/False _________________. Solder is never permitted to attach connections to the grounding conductor.

42. True/False __________________. Splices are never permitted in service-entrance conductors.

43. True/False __________________. It is not necessary to ground one wire on a two-wire DC system with not more than 300 volts between conductors.

44. End of test. STOP. Have you instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

GROUNDING

UNIT IV

ASSIGNMENT SHEET #1 - ANSWERS

1. The "voltage to ground" is less than 150 V.

2. Metal pipes; metal frames

3. a. Measuring from ground to the other conductor gives 230 V.

   b. The voltage to ground from one wire is not the same as from the other wire.

4. 115 V

5. Any of the conductors

6. At the point of service entrance

7. Equipment grounding

8. Same earth ground as the system ground

9. Equipment that a person could touch while simultaneously touching a grounded object.

10. A person in touch with earth ground touches a system that is accidentally in contact with ground.

11. Open protective overcurrent devices

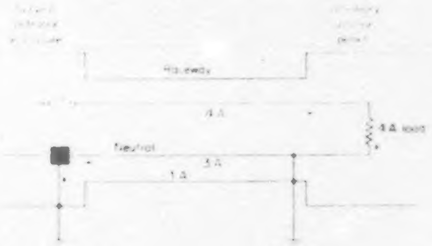
12. Provide a common ground point in the service entrance.

13. Service conductor

14. 350 to 600 MCM

15. The service entrance. Current could flow back through the equipment.

16.



17. The rating of the overcurrent device ahead of theequipment.

18. No; the equipment

19. 1.25

20. It is possible that overall resistance of the equipment will increase to a point where fault current won't flow and the overcurrent device won't open.

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ASSIGNMENT SHEET #1 - ANSWERS

21. Shock hazard, arcing, heating

22. A ribbon of aluminum that runs the entire length of the cable.

23. Twelve 115 V. lamps

24. Motors, machines, controllers

25. The grounded conductor must not be provided with an overcurrent device.

26. Switch, switch

27. 5 milliamps

28. Current inbalance

29. Yes

30. Yes

31. A. Faulty appliance with equipment ground.

    B. Ground fault on neutral conductors at the load side of the circuit breaker.

32. The GFCI will open under a ground fault but will not protect the user.

33. All conductors (except equipment ground) for a circuit must pass through a single sensor, and these conductors can't be shared by any other circuit.

GROUNDING

UNIT IV

ASSIGNMENT SHEET #2 - ANSWERS

1. Yes; it must be insulated, unless it is in a duct or conduit (see NEC, Article 230-30). There is an exception; bare copper for direct burial where bare copper is judged to be suitable for the soil conditions.

2. No; overcurrent-protection devices may not be installed in the grounded service conductor, unless a circuit breaker is used that opens all conductors of the circuit simultaneously (see NEC, Article 230-90b).

3. Yes, but it shall be placed in any permanently grounded conductor, except as follows: Where the overcurrent device simultaneously opens all conductors of the circuit. See Section 240-22 of the NEC. A fuse shall also be inserted in the grounded conductor when the supply is 3-wire, 3-phase AC, one conductor grounded. See Section 430-36 of the NEC.

4. The enclosures must be of an approved type for the location and must be mounted with at least a 1/4-inch air space between the wall or supporting surface (see NEC, Article 240-32).

5. Yes, AC circuits and systems shall be grounded as provided for in (a), (b), (c), or (d) in Section 250-5 of the NEC. Other circuits and systems shall be permitted to be grounded.

6. Circuits of less than 50 volts need not be grounded, unless they are supplied from systems exceeding 150 volts to ground, where they are supplied by transformers from ungrounded systems, or where they run overhead outside buildings (see NEC, Article 250-5a).

7. Yes, the grounded conductor must be run to each service. It need not be taken farther than the service equipment, if it will not be required in any of the circuits. This requirement went into effect January 1, 1964 (see NEC, Article 250-23).

8. Portable tools and appliances may have double insulation. If they have, they must be so marked and will not require grounding (see NEC, Article 250-45).

9. The grounding conductor for circuits is used for grounding equipment, conduit, and other metal raceways, including service conduit, cable sheath, etc. (see NEC, Article 250-53).

10. Threaded couplings and bosses should be made wrench tight, as should threadless couplings and connections in rigid conduit or EMT (electrical metallic tubing). Bonding jumpers should be used around concentric and eccentric knockouts (see NEC, Article 250-72).

ASSIGNMENT SHEET #2 - ANSWERS

11. The electrical continuity of metal raceway or metal-sheathed cable which contains any conductor other than service-entrance conductors or more than 250 volts to ground shall be assured by one of the methods specified in Section 250-72, (a) - (e) and 250-76.

12. Pipe electrode must be at least 3/4 inch trade size and, if made of iron or steel, they must be galvanized or otherwise metal-coated to prevent corrosion; they must also be driven to a depth of at least 8 feet (see NEC, Article 250-83).

13. Splices are not permitted; grounding conductors must be one piece for their entire length (see NEC, Article 250-91).

14. Aluminum may not come in contact with masonry or the earth and cannot be run closer than 18 inches from the earth; also the grounding conductor of a wiring system shall be copper or other corrosion resistant material (see NEC, Article 250-91a and 250-92).

15. Solder is never permitted; pressure connectors are to be used (see NEC, Article 250-113).

16. Yes, service fuses, meters, high-impedance shunt circuits (such as potential coils of meters), supply conductors for time switches, surge-protection capacitors, instrument transformers, lightning arresters, and circuits for emergency systems (such as fire-pump equipment, etc,) (see NEC, Section 230-82).

17. No, they must not be spliced; where they supply a meter, they may be broken as necessary for connecting the meter (see NEC, Section 230-46).

18. To limit the excess voltage to ground, which might occur from lightning or exposure to other higher voltage sources (see NEC, Article 250-1).

19. Yes, in practically every case, although there are a few exceptions (see NEC, Article 250-3).

20. A "made" grounding electrode may be a driven pipe, driven rod, buried plate, or other device approved for the purpose of grounding the equipment and must conform to certain Code requirements (see NEC, Article 250-83).

GROUNDING

UNIT IV

TEST ANSWERS

1. Voltage to ground - 150 V.

2. Metal pipes

3a. Measuring from ground to the other conductor gives 230 V.

 b. The voltage to ground from one wire is not the same as from the other wire.

4. 3-phase, 4-wire

5. 3-phase, 3-wire

6. Service entrance

7. Equipment grounding

8. All equipment

9. ...could touch while simultaneously touching a grounded object.

10. Fault current flows

11. Protective overcurrent devices

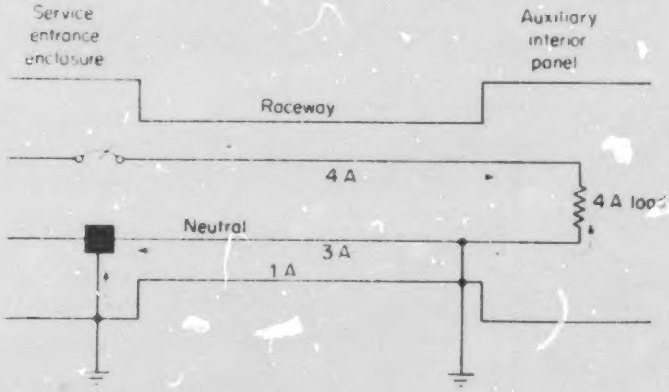
12. A system and equipment

13. Ground conductor

14. Copper, No. 0 AWG

15. Neutral conductor

16.


Service entrance enclosure
Auxiliary interior panel
Raceway
4 A
4 A load
Neutral
3 A
1 A

17. Size; rating

TEST ANSWERS

18. 3-phase, 3-wire system; equipment

19. Aluminum 350 MCM; 1.25

20. Fault current won't flow and the overcurrent device won't open

21. Making proper electrical contact

22. Low resistance

23. Twelve 115 V. lamps

24. Ground detectors

25. A "solid neutral" electrical

26. Grounded conductor; all conductors

27. Temperature level

28. Hot and neutral conductor

29. Yes

30. Yes

31. GCFI units

32. The GFCI will open under a ground fault but will not protect the user.

33. All conductors (except equipment ground) for a circuit must pass through a single sensor and these conductors can't be shared by any other circuit.

34. No

35. False

36. a. Where supplied by transformers if the transformer supply system exceeds 150 volts to ground.

    b. Where supplied by transformers if the transformer supply system is ungrounded.

    c. Where installed as overhead conductors outside the building.

    d. Where the system can be so grounded that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

    e. Where the system is norminally rated 480Y/277-volt, 3-phase, 4-wire in which the neutral is used as a circuit conductor.

TEST ANSWERS

f. Where the system is norminally rated 240/120 volt, 3-phase, 4-wire in which the midpoint of one phase is used as a circuit conductor.

g. Where a service conductor is uninsulated in accordance with Section 230-4.

37. Yes

38. Grounding equipment, conduit and other metal raceways.

39. Threadless fittings; two locknuts

40. False

41. True

42. True

43. False

POWER DISTRIBUTION

UNIT V

TRANSFORMERS

TRANSFORMERS

UNIT V

OBJECTIVE

After completing this unit, the student should be albe to describe and calculate transformer quantities and sketch transformer applications. This knowledge will be shown by completing assignment sheets, lab procedures and test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Show in writing a knowledge of transformer principles.
2. Describe how to check transformers for their phase relationship.
3. Describe how to check an unmarked transformer for its polarity.
4. Describe how to measure copper loss in a transformer.
5. Describe how to measure core loss in a transformer.
6. Describe how to measure winding inbalance.
7. Sketch the wiring diagram for a single phase, 120/240 V, 3-wire transformer.
8. Sketch the wiring diagram for a 3-phase delta-to-wye transformer.
9. Sketch the wiring diagram for a 3-phase, delta-to-delta transformer.
10. Sketch the wiring diagram for a 3-phase, wye-to-delta transformer.
11. Calculate the power acting, currents, and input and output currents for a delta-to-wye transformer.
12. Sketch the wiring diagram for an autotransformer.
13. Describe how the power rating of an autotransformer may be reduced.
14. Sketch the wiring diagram necessary to obtain 600 V, 3-phase from 480 V, 3-phase using an autotransformer.
15. Describe how to temporarily repair a delta-to-delta transformer when a set of windings go bad.
16. List two types of instrument transformers.

SPECIFIC OBJECTIVES

17. Demonstrate the ability to

    A. Analyze transformers

    B. Construct Wye-Wye, Delta-Delta, Wye-Delta, and Delta-Wye transformers.

TRANSFORMERS

UNIT V

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure, assignment, and lab sheets.

   C. Make transparencies.

   D. Discuss unit and specific objective.

   E. Discuss assignment and lab sheets.

   F. Summarize characteristics of transformers.

   G. Demonstrate wiring of transformers.

   H. Demonstrate troubleshooting and repair of transformers.

   I. Assist students in connecting various transformers.

   J. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheets.

   C. Take test.

TRANSFORMERS

UNIT V

INSTRUCTIONAL MATERIAL

I. Included in this unit:

- A. Objective sheet.
- B. Procedure sheets.
- C. Assignment sheets.
- D. Lab sheets.
- E. Test.
- F. Answers to assignment sheets.
- G. Answers to test.

II. References

A. Graham, Kennard C., Industrial and Commercial Wiring, Chicago, IL, American Technical Society, 1963.

B. Smith, Robert L., Electrical Wiring, Industrial, Albany, New York, Delmar Publishing, 1984.

C. Lenk, John D., Handbook of Simplified Electrical Wiring Design, Englewood Cliffs, New Jersey, Prentice - Hall, 1975.

D. Fardo and Prewitt, Electrical Experimentation & Practical Applications, Indianapolis, IN, Howard W. Sams & Co., 1978.

E. Patrick and Fardo, Experimenting with Industrial Electrical System, Indianapolis, IN, Howard W. Sams & Co., 1978.

F. Patrick and Fardo, Electrical Power System Technology, Indianapolis, IN, Howard W. Sams, 1979.

C. Palmquist, Roland E., Questions and Answers for Electrician Examinations, Indianapolis, IN., Howard W. Sams, 1979.

III. Related Material

A. National Electric Code, Quincy, MA, National Fire Protection Association, 1983.

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TRANSFORMERS

UNIT V

PROCEDURE SHEET

_____1. Study — Chapter 5, Applications of Transformers.

_____2. Complete — Assignment Sheet #1 - Principles and Applications of Transformers.

_____3. Stop — Have your instructor evaluate Assignment Sheet #1. If the instructor approves your performance, continue to Step 4. Otherwise repeat Steps 1-3.

_____4. Complete — Assignment Sheet #2, questions relating to transformer principles.

_____5. Stop — Have your instructor evaluate Assignment Sheet #1. If the instructor approves your performance, continue to Step #6. Otherwise repeat Step 1, 4 and 5.

_____6. Do — Lab Procedures.

_____7. Stop — Have the instructor approve your performance.

_____8. Study — Chapter 5 in your text; assignment sheets.

_____9. Take — Transformer Test.

TRANSFORMERS

UNIT V

ASSIGNMENT SHEET #1 - SKETCHING, CALCULATING AND DESCRIBING TRANSFORMERS

1. The main purpose of transformers if to provide ________________________ ________________________ for use by ____________ ________________________ from a ____________ ________________________.

2. Isolation transformers differ from ordinary transformers in that they have ________________________ ________________________.

3. Low voltage windings are marked with an ________________________.

4. High voltage windings are marked with a ________________________.

5. Even numbered terminals have the same ____________, ____________ ____________ ____________.

6. Small transformers are not numbered rather the polarity is marked by ________________________.

7. If an odd winding is connected to an even winding of windings producing 120 V, the result will be ________________________.

8. Never connect any winding to a voltage higher than the ____________ for that particular winding.

9. The VA or KVA rating of a transformer shows ________________________ of load that can be connected.

10. Two common losses of transformers are:

    a.

    b.

ASSIGNMENT SHEET #1

11. The efficiency of a transformer is found by dividing ______________ ____________ by ____.

12. To check identical transformers for three-phase relationship, a __________________________ and _____________________ are used.

13. If in checking phase, identical transformers are connected in series, the voltmeter reads ____________________________________ and if they are connected in parallel, the voltmeter reads ____.

14. To check the polarity of an unmarked transformer, a _________________ ______________________ and a _________________________ are used.

15. The polarity relationship of a single primary and single secondary winding is found by ____ ____ ____.

16. The proper steps for determining the phase relationship of multitransformers is:

1.

2.

3.

4.

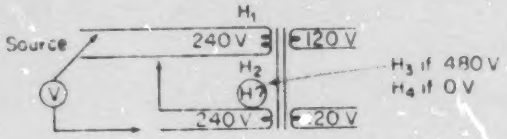
5.

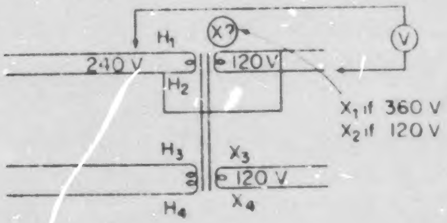
6.

7.

8.

ASSIGNMENT SHEET #1


H$_1$
Source
240 V
120 V
H$_2$
H?
H$_3$ if 480 V
H$_4$ if 0 V
240 V
120 V

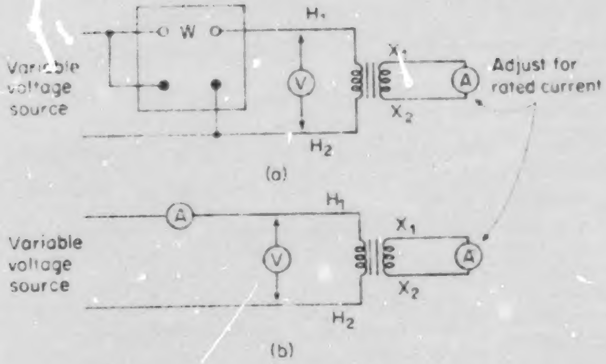

H$_1$
X?
V
240 V
120 V
H$_2$
X$_1$ if 360 V
X$_2$ if 120 V
H$_3$
X$_3$
120 V
H$_4$
X$_4$

17. Copper loss can be measured by

    1.

    2.

    3.


W
H$_1$
Variable voltage source
V
X$_1$
X$_2$
A
Adjust for rated current
H$_2$
(a)
A
H$_1$
X$_1$
Variable voltage source
V
A
X$_2$
H$_2$
(b)

18. Core loss can be measured by:

    1.

    2.

    3.

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ASSIGNMENT SHEET #1

19. Percentage of impedance can be found by:

1.

2.

20. To measure winding balance: ______________________________

____

____.

21. Sketch a wiring diagram forthe following transformers:

a. Single-phase, 120/240 V, 30 wire:

b. Single-phase, 120 V, 2-wire (maximum cement):

ASSIGNMENT SHEET #1

c. Single-phase, 120/240 V (with reduced high voltage):

22. Sketch a 3-phase, delta-to-wye wiring diagram:

23. Sketch a 3-phase, delta-to-delta wiring diagram:

ASSIGNMEMT SHEET #1

24. Sketch a 3-phase, wye-to-delta wiring diagram:

25. For a delta-to-wye three-phase power transformer that has 480 V high voltage winding and two 120 V low voltage windings--assume 480 V source, 90 kw, power factor .7 requiring 120 V:

a. Minimum power rating for each transfer:

b. Current in primary and secondary of each transformer:

c. Input line current from 480 V. source:

ASSIGNMENT SHEET #1

d. Output line current at the wye load:

26. Sketch the wiring diagram of an autotransformer.

27. How can the power rating of an autotransformer be reduced.

___

___

___

ASSIGNMENT SHEET #1

28. Sketch the wiring diagram necessary to have 120 V single-phase from 240 V three-phase using an autotransformer.

29. Sketch the wiring diagram necessary to obtain 600 V three-phase from 480 V, three-phase using an autotransformer.

30. ______________________________transformer is one way to change three-phase to two-phase.

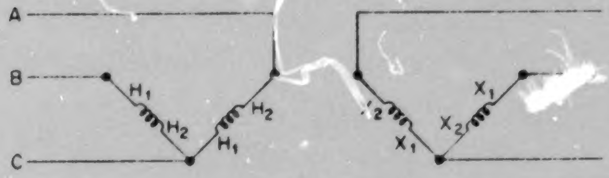
ASSIGNMENT SHEET #1

31. Sketch the wiring necessary to connect three-phase to two-phase.

32. The open delta transformer is used only as a ______________________

____________________system.

33. If a set of windings in a delta-to-delta system becomes defective an open delta system can be used by changing the wiring below to:



34. Two types of instrument transformers are:

a.

b.

ASSIGNMENT SHEET #1

35. Sketch a wiring diagram for a current instrument transformer.

36. Sketch a wiring diagram for a voltage instrument transformer.

TRANSFORMERS

UNIT V

ASSIGNMENT SHEET #2 - QUESTIONS RELATING TO TRANSFORMERS

Use your text, Chapter 5, to complete the following assignment.

1. How many degrees are between the three phases of a three-phase circuit?

2. Name two basic types of transformers.

3. How far out of phase are the primary and secondary voltages of a transformer?

4. What connections must be made to have the primary and secondary of a transformer in phase?

5. According to ANSI (American National Standards Institute), how are the leads of a transformer marked?

6. Is the current and voltage in the high side of a transformer and the current and voltage in the low side of a transformer directly proportional? Draw a diagram showing this relationship.

ASSIGNMENT SHEET #2

7. How are current transformers rated? For what do the rotaing numbers of a transformer stand?

8. Are there precautions to be taken when working with current transformers?

9. How would two-single-phase transformers be connected to secure a three-phase output from a three-phase input?

10. If two single-phase transformers are connected in an open Delta arrangement do they supply their full output rating?

11. Name at least four cases where autotransformers may be used?

TRANSFORMERS

UNIT V

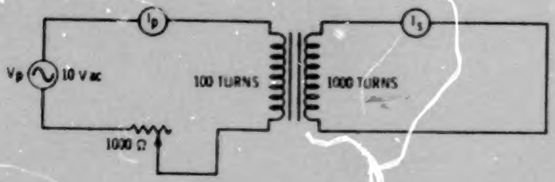
LAB SHEET #1 - ANALYZING TRANSFORMERS

I. Equipment

A. 1-Step-up transformer
B. 2-A/C current meter
C. 1-1K Ω potentiometer
D. A/C power source (variable)

II. Procedure

A. Connect the circuit shown below:


I_p
I_s
V_p
10 V ac
100 TURNS
1000 TURNS
1000 Ω

B. Apply 10 V A/C, vary the potentiometer from 100 Ω -1000 Ω and record in the following table the primary and secondary current.

LAB SHEET #1

C. Apply 20 VAC and record the primary and secondary current as you vary the potentiometer from 100 - 1000

D. Apply 30 VAC and record the primary and secondary current as you vary the potentiometer from 100 - 1000

Potentiometer Resistance	10 V ac		20 V ac		30 V ac	
	I_p	I_s	I_p	I_s	I_p	I_s
100 Ω						
200 Ω						
400 Ω						
600 Ω						
800 Ω						
1000 Ω						

E. Discuss the variation of the secondary current as a function of primary current.

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LAB SHEET #1

F. Discuss the variation of the primary and secondary current as a function of applied voltage.

G. Show your results to your instructor.

H. Put up your equipment.

TRANSFORMERS

UNIT V

LAB SHEET #2 - CONSTRUCTING WYE-WYE, DELTA-DELTA, WYE-DELTA AND DELTA-WYE TRANSFORMERS

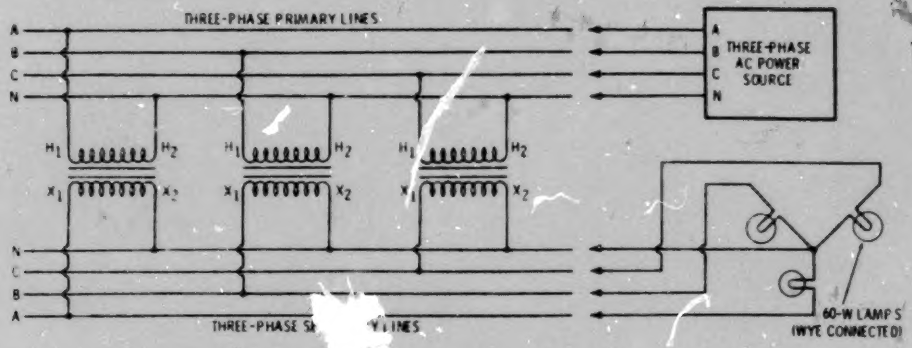
I. Equipment

A. 1-three-phase transformer
B. 1-3-phase AC power source
C. 3-60 watt lamp
D. 1-VOM
E. Hook-up wire

II. Procedure

A. Connect the wye-wye transformer shown in Figure 1

FIGURE 1


THREE-PHASE PRIMARY LINES
A
B
C
N
H1
H2
X1
X2
THREE-PHASE AC POWER SOURCE
N
C
B
A
THREE-PHASE S LINES
60-W LAMPS (WYE CONNECTED)

B. Apply sufficient 3-phase volts to the transformers.

C. Complete the following table of current and voltage measurements:

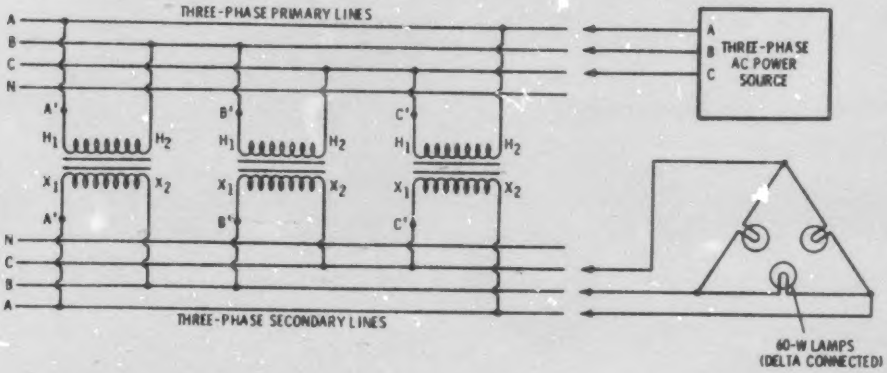
Primary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	V_{A-N}	V_{B-N}	V_{C-N}	I_A	I_B	I_C
Secondary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	V_{A-N}	V_{B-N}	V_{C-N}	I_A	I_B	I_C

LAB SHEET #2

D. Turn off the power.

E. Now wire the delta-delta circuit shown in Figure 2.

FIGURE 2


THREE-PHASE PRIMARY LINES
A
B
C
N
A'
B'
C'
H1
H2
X1
X2
THREE-PHASE AC POWER SOURCE
THREE-PHASE SECONDARY LINES
60-W LAMPS (DELTA CONNECTED)

F. Turn the power source on to the same voltage as before.

G. Complete the following table of current and voltage measurements.

Primary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	$I_{L(A)}$*	$I_{L(B)}$*	$I_{L(C)}$*	$I_{p(A)}$†	$I_{p(B)}$†	$I_{p(C)}$†

Secondary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	$I_{L(A)}$*	$I_{L(B)}$*	$I_{L(C)}$*	$I_{p(A)}$†	$I_{p(B)}$†	$I_{p(C)}$†

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LAB SHEET #2

H. Turn off the power

I. Using Figure 1 and Figure 2 wire a wye-delta transformer where the wye is wired to the power source and the delta side is wired to the load.

J. Turn the power source on to the same voltage as before.

K. Again record the current and voltage of the wye-delta transformer in the following table.

Primary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	V_{A-N}	V_{B-N}	V_{C-N}	I_A	I_B	I_C

Secondary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	$I_{L(A)}^{*}$	$I_{L(B)}^{*}$	$I_{L(C)}^{*}$	$I_{p(A)}^{\dagger}$	$I_{p(B)}^{\dagger}$	$I_{p(C)}^{\dagger}$

L. Turn off the power.

M. This time use Figure 1 and Figure 2 to wire a delta-wye circuit where the delta is connected to the power source and the wye is connected to the local.

N. Turn the power source on to the same valve as before.

O. Measure and record the currents and voltage for the delta-wye transformer in the following table.

Primary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	$I_{L(A)}^{*}$	$I_{L(B)}^{*}$	$I_{L(C)}^{*}$	$I_{p(A)}^{\dagger}$	$I_{p(B)}^{\dagger}$	$I_{p(C)}^{\dagger}$

Secondary Measurements								
V_{A-B}	V_{B-C}	V_{A-C}	V_{A-N}	V_{B-N}	V_{C-N}	I_A	I_B	I_C

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LAB SHEET #2

P. Be prepared to discuss your results with your instructor.

Q. Show your observations to your instructor.

R. Turn off the power.

S. Put up your equipment.

TRANSFORMERS

UNIT V

TEST

NAME:______________________________ SCORE:__________

1. Give complete answers using transformer principles.

   a. What is the phase relation between the three phases of a three-phase circuit?

   b. Ordinarily, what is the phase relationship between the primary and secondary voltages of a transformer?

   c. How are the leads of a transformer marked, according to ANSI (American Natioanl Standards Institute)?

   d. How are current transformers rated?

   e. Is it possible to connect two single-phase transformers to secure a three-phase output from a three-phase input?

   f. Where may autotransformers be used?

TEST

2. Describe using sketches how to check transformers for
   a. phase relationship

   b. polarity

3. Describe how to measure for a transformer its:
   a. Copper loss

   b. Core loss

   c. Winding in balance

TEST

4. Sketch a wiring diagram for a single-phase, 120/240 V, 3-wire transformer:

5. Sketch a wiring diagram for a 3-phase, delta-to-wye transformer:

6. Sketch the wiring diagram for a 3-phase, delta-to-delta transformer:

TEST

7. Sketch a wiring diagram for a wye-to-delta transformer:

8. Assume 480 V source, 70 kw, power faster .85, requiring 120 V and calculate for three delta-to-wye transformers that have 480 V at their high voltage widnings and two 120 V low voltage windings:

   a. Minimum power rating for each transfer:

   b. Current in primary and secondary of each transformer:

   c. Input line current from 480 V source:

   d. Output line current at the wye load:

TEST

9. Sketch a wiring diagram for an autotransformer:

10. Describe how the power rating for an autotransformer may be reduced.

11. Sketch the wiring necessary to obtain 600 V, 3-phase from 480 V, 3-phase using an autotransformer.

TEST

12. Describe how to temporarily repair a dalta-to-delta transformer when a set of windings go bad.

13. List two types of instrument transformers:

14. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, CONGRATULATIONS! You have finished this section. Go on to the next section. If additional study is necessary ask your instructor about study requirements and possible retesting.

TRANSFORMERS

UNIT V

ASSIGNMENT SHEET #1 - ANSWERS

1. Several different voltages; different loads; single voltage source.

2. Same primary and secondary windings.

3. "X"

4. "H"

5. Instantaneous positive polarity

6. A dot

7. 240 V

8. Rating

9. Safe limit

10. a. Copper loss (I^2R)
    b. Core

11. Output power by input power

12. Power source and voltmeter

13. 0 V, 2xV

14. Voltage source and voltmeter

15. Apply a voltage to the primary, in series, the low and high voltage equal the reading on the voltmeter. In parallel, the voltmeter will show the difference.

16. a. Connect any winding to the proper voltage according to the nameplate information.

    b. Arbitararily assign H_1 and H_2 to this source winding (or X_1 and X_2 if the winding is of low voltage).

    c. Check the other three voltages. They should

    d. Connect one lead of the other 240-V winding to H_2 of the source winding.

    e. If the voltmeter indicates 480 V, the voltages are additive, and the top terminal is odd-numbered of H_3.

ASSIGNMENT SHEET #1 - ANSWERS

f. If the voltmeter indicates 0 V, the voltages are opposing, and the terminal is even-numbered or H_4.

g. If the transformer is three-phase, repeat the procedure for the third high-voltage winding (H_5 and H_6).

h. Repeat the procedure with each of the 120 V windings. If the voltmeter reads the sum of 240 and 120 V winding is X_1. If the voltmeter shows 240-120 V, or 120 V, the terminal is X_2. Terminals X_3 and X_4 (as well as X_5 and X_6) can be found in the same way.

17. a. With either circuit, increase the variable voltage source from zero until the ammeter in the low-voltage (short circuit) winding indicates the rated current for that winding. Typically, the variable voltage source will be very low in relation to the rated winding voltage.

b. For the circuit of Fig. 5-6a, simply note the wattmeter reading to determine the copper loss.

c. For the circuit of Fig. 5-6b, multiply the variable voltage indication by the primary or input ammeter reading to find the copper loss.

18. a. With either circuit, apply the rated voltage to the low-voltage winding. All other windings must be open circuit.

b. For the circuit of Fig. 5-7a, simply note the wattmeter reading to find the core loss.

c. For the circuit of Figure 5-7b, multiply the voltmeter reading by the ammeter reading to find the core loss.

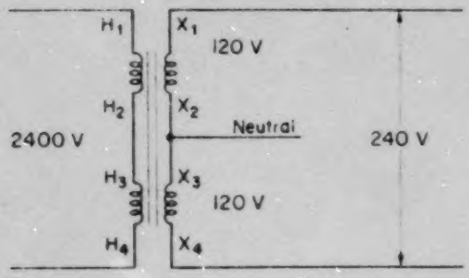
19. a. Increase the variable voltage source from zero until the ammeter in the low-voltage (short-circuit) winding indicates the rated current for that winding. Typically the variable voltage source will be very low in relation to the rated winding voltage.

b. The percentage of impedance is found when the variable source voltage is divided by the rated voltage for the high-voltage winding and the result multiplied by 100. For example, assume that 6 V must be applied to a 240-V high-voltage winding to produce an ammeter reading (in the low-voltage winding) equal to the rated winding current. Then the percentage of impedance is (6/240) X 100 = 2.5 per cent.

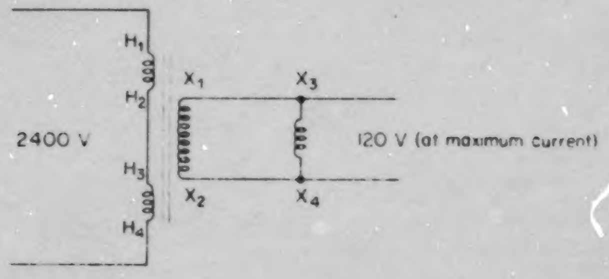
20. Measure voltages on both sides of the center tap.

ASSIGNMENT SHEET #1 - ANSWERS

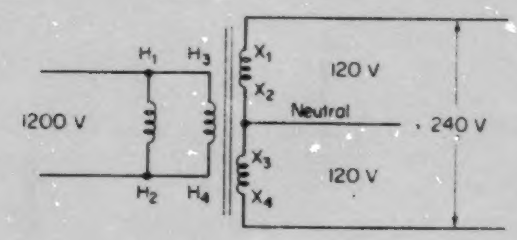
21. a. Single-phase transformer connections for 120-240 V, 3-wire:


H1
H2
2400 V
H3
H4
X1
120 V
X2
Neutral
240 V
X3
120 V
X4

b. Single-phase transformer connections for 120 V, 2-wire, at maximum current:

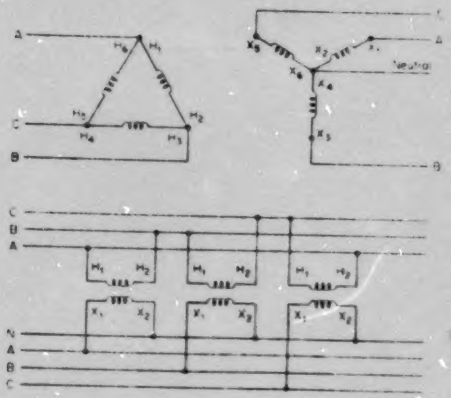

H1
H2
2400 V
H3
H4
X1
X3
120 V (at maximum current)
X2
X4

c. Single-phase transformer connections for 120-240 V, 3-wire (reduced high voltage):

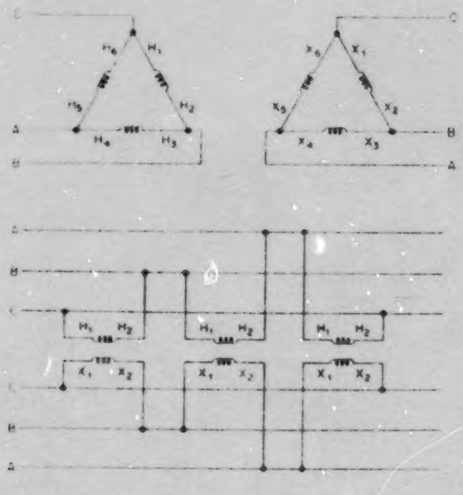

H1
H3
1200 V
H2
H4
X1
120 V
X2
Neutral
240 V
X3
120 V
X4

ASSIGNMENT SHEET #1 - ANSWERS

22. 3-phase transformer connections for delta-to-wye.


A
H6
H1
H5
H2
C
H4
H3
B
X5
X2
X1
C
A
X6
Neutral
X4
X3
B
C
B
A
H1
H2
H1
H2
H1
H2
X1
X2
X1
X2
X1
X2
N
A
B
C

23. 3-phase transformer connections for delta-to-delta.


C
H6
H1
H5
H2
A
H4
H3
B
C
X6
X1
X5
X2
B
X4
X3
A
A
B
C
H1
H2
H1
H2
H1
H2
X1
X2
X1
X2
X1
X2
C
B
A

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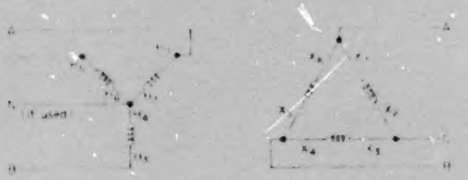
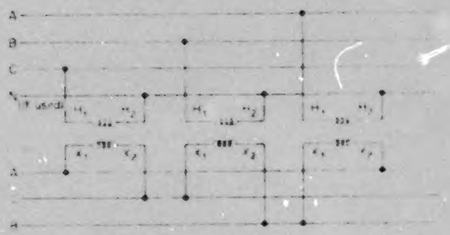
ASSIGNMENT SHEET #1 - ANSWERS

24. 3-phase transformer connections for wye-to-delta.





25. a. $\frac{90 \text{ kw}}{3}$ = 30 kw minimum transformer rating

$\frac{90 \text{ kw}}{0.7\text{x}3}$ = 42.86 kva/transformer

b. $\frac{42{,}860}{480 \text{ V}}$ = 89.29A

c. $\frac{42860 \text{ VA}}{120 \text{ V}}$ = 357.17 A

d. $\frac{42.86 \text{ kva}}{1.732\text{x}480}$ = 51.55 A

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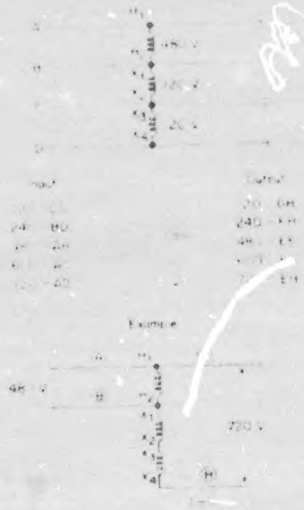
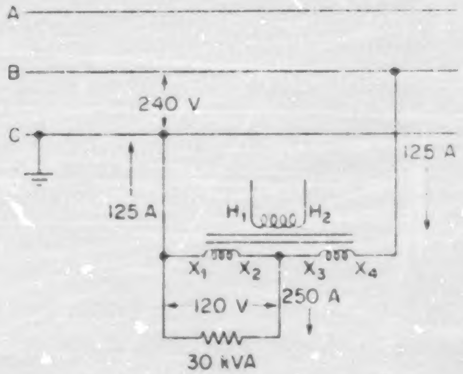
ASSIGNMENT SHEET #1 - ANSWERS

26. Basic autotransformer connections.


480 V
Example
720 V

27. Connect the inputs in Problem 26 AB-480 and the outputs EH-720.

28. Example of autotransformer used in tap 120 V single-phase power from 240 V 3-phase.


A
B
C
240 V
125 A
125 A
H₁
H₂
X₁
X₂
X₃
X₄
120 V
250 A
30 kVA

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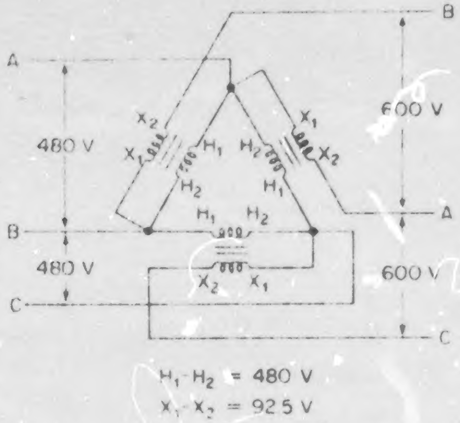
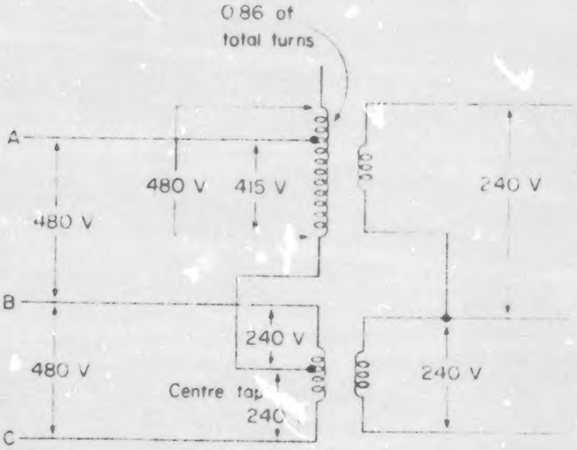
ASSIGNMENT SHEET #1 - ANSWERS

29. Example of autotransformer used to provide 600 V, 3-phase, from 480 V, 3-phase:


A
B
C
480 V
480 V
600 V
600 V
B
A
C
X_1
X_2
H_1
H_2
H_1-H_2 = 480 V
X_1-X_2 = 92.5 V

30. Scott or T

31. Example of Scott or T-transformer connection to provide 240 V, 2-phase from 480 V, 3-phase:


0.86 of total turns
A
B
C
480 V
480 V
480 V
415 V
240 V
240 V
240 V
Centre tap
240

32. Temporary

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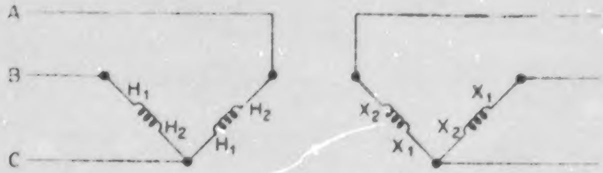
ASSIGNMENT SHEET #1 - ANSWERS

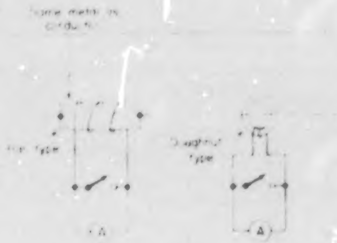
33. Open delta transformer connections:


A
B
C
H_1
H_2
H_2
H_1
X_2
X_1
X_2
X_1

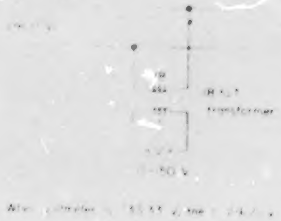
34. a. Voltage

    b. Current

35. Typical current transformers:


Doughnut type
A
A

36. Typical voltage transformer:


transformer
0-150 V

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TRANSFORMERS

UNIT V

ASSIGNMENT SHEET #2 - ANSWERS

1. They are 120 electrical degrees apart.

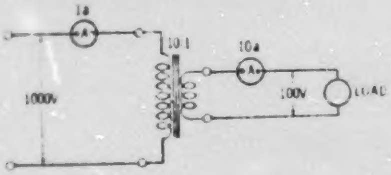
2. The isolation type--the two windings are physically isolated and electrically insulated from each other; and the autotransformer type--there is only one coil with a tap or taps taken off of it to secure other voltages (the primary is part of the secondary and the secondary is part of the primary).

3. They are 180° out of phase.

4. Yes, by changing the connections on one side of the transformer.

5. The high side of the transformer is marked H_1, H_2, etc. The low side of the transformer is marked X_1, X_2, etc.

6. The current in one side of a transformer is inversely proportional to the current in the other side, with respect to the turns ratio, while the voltage across one side of a transformer is directly proportional to the voltage across the other side, with respect to the turns ratio; these are illustrated as follows: (current-voltage relationship between the high side and the low side of a transformer)



7. The first number is the total current that the transformer is supposed to handle, and the second figure is the current on the secondary when the full-load current is flowing through the primary. For example, a 50-to-5 rating would have a multiplier of 10 (K = 10).

8. The secondary must never be opened when the primary circuit is energized. If it is necessary to disconnect an instrument while the circuit is energized, the secondary must be short circuited. If the secondary is opened while the circuit is energized, the potential on the secondary may reach dangerously high values. By short circuiting the secondary, damage is avoided and the voltage on the secondary is kept within safe limits.

ASSIGNMENT SHEET #2 - ANSWERS

9. They would have to be connected in an open Delta.

10. No. Each transformer is only capable of supplying 86.6% of its output rating.

11. (a) Where the system being supplied contains an identified grounded conductor that is solidly connected to a similar identified grounded conductor of the system supplying the autotransformer (see NEC, Section 210-9); (b) where an autotransformer is used for starting or controlling an induction motor (see NEC, Article 430-82b); (c) where an autotransformer is used as a dimmer, such as in theaters (see NEC, Article 520-25c); (d) as part of a ballast for supplying lighting units (see NEC, Section 410-78). For voltage bucking and boosting see NEC, Section 210-9 Exception.

TRANSFORMERS

UNIT V

TEST ANSWERS

1. a. They are 120 electrical degrees apart.

   b. They are 180° out of phase.

   c. The high side of the transformer is marked H_1, H_2, etc. The low side of the transformer is marked X_1, X_2, etc.

   d. They are rated at 50 to 5 , 100 to 5, etc. The first number is the total current that the transformer is supposed to handle, and the second figure is the current on the secondary when the full-load current is flowing through the primary. For example, a 50-5 rating would have a multiplier of 10 (K = 10).

   e. Yes; they would have to be connected in an open Delta.

   f. (a) Where the system being supplied contains an identified grounded conductor that is solidly connected to a similar identified grounded conductor of the system supplying the autotransformer (see NEC Section 210-9); (b) where an autotransformer is used for starting or controlling an induction motor (see NEC, Article 430-82b); (c) where an autotransformer is used as a dimmer, such as in theaters (see NEC, Article 520-25c); (d) as part of a ballast for supplying lighting units (see NEC, Section 410-78). For voltage bucking and boosting see NEC, Section 210-9 Exception.

2. a. 0 V, 2xV

   b. Apply a voltage to the primary, in series, the low and high voltage equal the reading on the voltmeter. In parallel, the voltmeter will show the difference.

3a.(1) With either circuit, increase the variable voltage source from zero until the ammeter in the low-voltage (short circuit) winding indicates the rated current for that winding. Typically, the variable voltage source will be very low in relation to the rated winding voltage.

(2) For the circuit of Fig. 5-6a, simply note the wattmeter reading to determine the copper loss.

(3) For the circuit of Figure 5-6b, multiply the variable voltage indication by the primary or input ammeter reading to find the copper loss.

b.(1) With either circuit, apply the rated voltage to the low-voltage winding. All other windings must be open circuit.

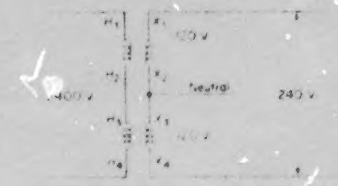
(2) For the circuit of Fig. 5-7a, simply note the wattmeter reading to find the core loss.

TEST ANSWERS

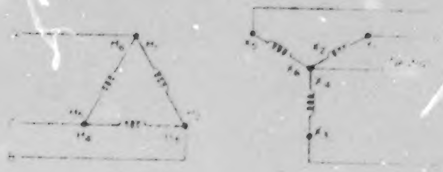
(3) For the circuit of Fig. 5-7b, multiply the voltmeter reading by the ammeter reading to find the core loss.

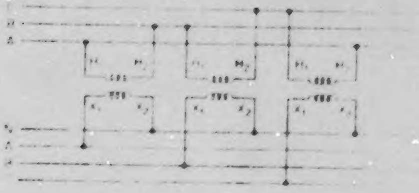
c. Measure voltages on both sides of the center tap.

4.

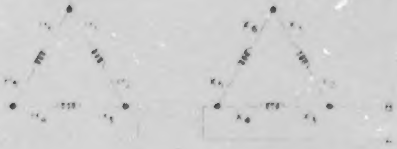

H1
X1
120 V
H2
X2
Neutral
2400 V
240 V
H3
X3
120 V
H4
X4

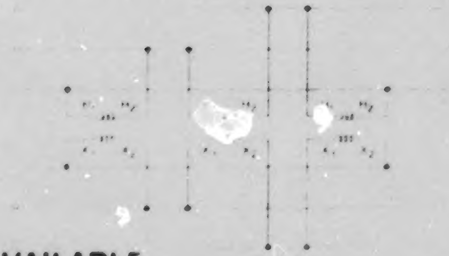
5.





6.





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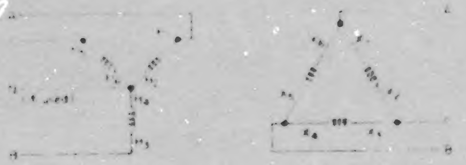
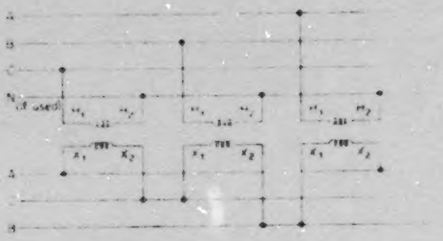
TEST ANSWERS

7.


A
N (if used)
H2
H3
B
X1
X2
B


A
B
C
N (if used)
H1
H2
H1
H2
H1
H2
X1
X2
X1
X2
X1
X2
A
B

8. a. $\frac{90 \text{ kw}}{3}$ = 30 kw minimum transformer rating

$\frac{90 \text{ kw}}{0.7\text{x}3}$ = 42.86 kva/transformer

b. $\frac{42{,}860}{480 \text{ V}}$ = 89.29 A

c. $\frac{42{,}860}{120 \text{ V}}$ = 357.17 A

d. $\frac{42.86 \text{ kva}}{1.732\text{x}480}$ = 51.55 A

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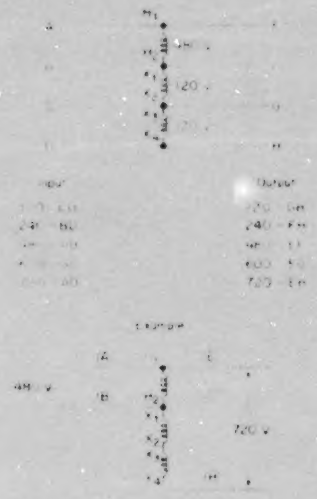
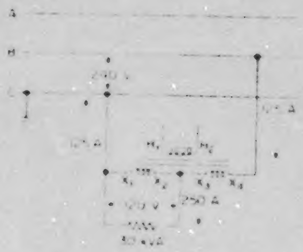
TEST ANSWERS

9.


120 V
120 V
Input
240 - BD
Output
240 - FH
720 - EH
480 V
720 V

10. Connect the inputs in Problem 26 AB-480 and the outputs EH-720.

11.


A
B
C
240 V
125 A
H_1
H_2
X_1
X_2
X_3
X_4
120 V
250 A
30 kVA

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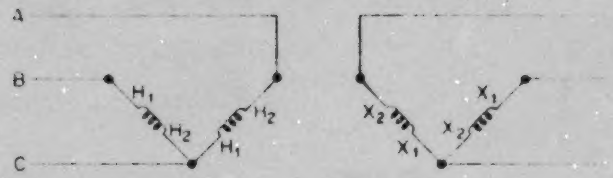
TEST ANSWERS

12.


A
B
C
H₁
H₂
H₂
H₁
X₂
X₁
X₂
X₁

13. a. Voltage

b. Current

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MECHANICAL DEVICES

UNIT I

INTRODUCTION TO DRIVES

INTRODUCTION TO DRIVES

UNIT I

OBJECTIVE

After completing the unit, the student should be able to label the parts of basic gears and make calculations involving gears. This knowledge will be shown by completing assignment sheets, lab procedures, chapter problems and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVE

After completing this unit, the student should be able to

1. Match terms associated with basics of drives to their correct definitions.
2. Demonstrate the ability to work problems involving mechanical components.
3. Demonstrate the ability to work problems involving gear diameters.
4. Demonstrate the ability to work problems involving gear teeth.
5. Demonstrate the ability to
    a. Construct basic mechanical drives
    b. Construct basic gear drives
    c. Construct basic gear drives to study the action of different gear teeth

INTRODUCTION TO DRIVES

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure sheet and Drives text.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss labs and problems from Drives.

   F. Discuss safety standard pertaining to drives and linkages.

   G. Discuss terminology of gears and gear teeth.

   H. Demonstrate various configuration of gears and gear teeth.

   I. Assist students in constructing and troubleshooting drives mechanics.

   J. Assist students in lab calculation.

   K. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheets.

   C. Take test.

INTRODUCTION TO DRIVES

UNIT I

INSTRUCTIONAL MATERIAL

I. Included in this unit:

  A. Objective sheet.

  B. Procedure sheet.

  C. Test.

  D. Answers to assignment sheets.

  E. Answers to test.

II. References

  A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

  B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

  C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

  A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development, 1981.

INTRODUCTION TO DRIVES

UNIT I

PROCEDURE SHEET

_____1. Study Mechanical Components, "Drives", Pages 1 - 8.

_____2. Complete Assignment Sheet #1 using "Drives", Pages 1-8.

_____3. Do Lab Procedure, Mechanical Components, Pages 8-10, your "Drives" manual.

_____4. Complete Problems, Page 10, your "Drives" manual.

_____5. Stop Have your instructor evaluate the problems. If your instructor is satisfied with your performance, continue to Step 6. Otherwise repeat Steps 1, 4 and 5.

_____6. Study Gear Diameters, "Drives", Pages 11-14.

_____7. Complete Assignment Sheet #2 using "Drives", Pages 11-14.

_____8. Do Lab Procedure, Gear Diameters, "Drives", Pages 15-16.

_____9. Complete Problems, "Drives", page 16.

____10. Stop Have your instructor evaluate the problems. If your instructor is satisfied with your performance, continue to Step 11. Otherwise repeat Steps 6, 9 and 10.

____11. Study Gear Teeth, "Drives", Pages 17-22.

____12. Complete Assignment Sheet #3 using "Drives", Pages 17-22.

____13. Do Lab Procedure, Gear Teeth, "Drives", Pages 22-24.

____14. Complete Problems, "Drives", Page 24.

____15. Stop Have your instructor evaluate the problems. If your instructor is satisfied with your performance, continue to Step 16. Otherwise repeat Steps 11, 14 and 15.

____16. Study Displacement Ratio, "Drives", Pages 25-27.
Velocity Ratio, "Drives", Pages 31-34.
Torque Ratio, "Drives", Pages 39-42.

PROCEDURE SHEET

____17.	Complete	Assignment Sheet #4 using "Drives", Pages 25-42.
____18.	Stop	Have your instructor review Assignment Sheet #4.
____19.	Review	Chapters 1-6, "Drives".
____20.	Complete	Test #1.
____21.	Stop	Have your instructor evaluate Test #1. If your instructor is satisfied with your performance, continue on to Unit II. Otherwise review the areas suggested by your instructor and repeat Steps 20 and 21.

INTRODUCTION TO DRIVES

UNIT I

ASSIGNMENT SHEET #1 - TERMS ASSOCIATED WITH GEARS - MECHANICAL COMPONENTS

Find the correct definitions for the following terms from Pages 1-8.

1. Spur Gear -
2. Commercial Gears -
3. Precision Gears -
4. Ultra-Precision Gears -
5. Hub Gear -
6. Hubless Gear -
7. Hub -
8. Staking -
9. Dutch Pinning -
10. Split Hub -
11. Split Collet and Chuck -
12. Bearings -
13. Backlash -

INTRODUCTION TO DRIVES

UNIT I

ASSIGNMENT SHEET #2 - TERMS ASSOCIATED WITH GEARS - GEAR DIAMETERS.

Find and write the correct definition to each of the following terms from Pages 11-14.

1. Outside Circle -
2. Outside Radius (R_O) -
3. Outside Diameter (D_O) or (OD) -
4. Root Circle -
5. Root Radius (R_R) -
6. Root Diameter (D_R) -
7. Pitch Circle -
8. Pitch Radius (R,r) -
9. Pitch Diameter (D,d) -
10. Pinion -
11. Gear -
12. Center Distance (C) -
13. Tooth Count (N,n) -
14. Shaft Diameter (d_S) -
15. Outside Shaft Spacing (X) -

INTRODUCTION TO DRIVES

UNIT I

ASSIGNMENT SHEET #3 - TERMS ASSOCIATED WITH GEARS - GEAR TEETH.

Find the correct definitions for the following terms from Pages 17-22.

1. Involute Curve -
2. Base Circle -
3. Tooth Face -
4. Addendum (a) -
5. Dedendum (d) -
6. Clearance (c) -
7. Whole Depth -
8. Working Depth -
9. Tooth Thickness (T) -
10. Chordal Thickness -
11. Width -
12. Line of Action -
13. Path of Contact -
14. Pressure Angle (ϕ) -
15. Pitch -
16. Diametral Pitch (P, P_d or DP) -
17. Circular Pitch (P_c) -
18. Module -
19. 20-Degree Stub Involute -
20. Fellows Stub Tooth -

INTRODUCTION TO DRIVES

UNIT I

ASSIGNMENT SHEET #4 - TERMS ASSOCIATED WITH DISPLACEMENT RATIO, VELOCITY RATIO, AND TORQUE RATIO

Find the correct definitions for the following terms from Pages 25-42.

1. Pitch Point -
2. Pitch Circle Displacement (Sp, Sg) -
3. Angular Displacement (θ_p, θ_g) -
4. Velocity -
5. Tooth Velocity -
6. Pitch Circle Velocity (V_p, V_g) -
7. Angular Velocity (ω_p, ω_g) -
8. Tachometer -
9. Stroboscope -
10. Work (W) -
11. Power (P) -
12. Horsepower (HP) -
13. Energy -
14. Potential Energy (PE) -
15. Kinetic Energy (KE) -
16. Torque (T) -
17. Radian -

INTRODUCTION TO DRIVES

UNIT I

TEST

NAME____SCORE__________

1. Match terms to their correct definitions. Place the correct number in the blank.

_____a. A disc wheel with involute teeth cut at 90^0 to its face.

_____b. Relatively high quality gears with smaller tolerance levels and higher cost than the commercial type.

_____c. A one piece gear and hub made from a single piece of material. Cost is relatively high because of excess material waste and machine time in making the hub.

_____d. Material protruding from the side of a gear or pulley by which the gear is fastened to a shaft.

_____e. A method of attaching a hub to a gear by drilling a dowel hole at their union, perpendicular to the gear face (similar to a common keyway), then pressing a dowel pin into the hole.

_____f. A device used to fasten a hubless gear to a shaft when frequent disassembly is necessary.

_____g. The play between the teeth of mated gears.

_____h. A circle circumscribing the gear.

_____i. The diameter of the "outside circle"

_____j. The radius of the "root circle"

_____k. A circle indicating the effective size of the gear (between the root and outside circles)

_____l. The diameter of the pitch circle for the gear and pinion respectively.

1. Outside Circle
2. Root Radius (R_R)
3. Outside Shaft Spacing (X)
4. Backlash
5. Spur Gear
6. Work (W)
7. Potential Energy (PE)
8. Tachometer
9. Velocity
10. Horsepower (HP)
11. Precision Gears
12. Split Collet and Chuck
13. Dutch Pinning
14. Pitch Diameter (D,d)
15. Outside Diameter (D_O) or (OD)
16. Tooth Count (N,n)
17. Addendum (a)
18. Clearance (c)
19. Line of Action
20. Diametral Pitch (P,P_d or DP)

TEST

_____m. The larger of two meshed gears when speaking of a gear and pinion

_____n. The number of teeth cut around the gear

_____o. The distance between the outside of the shafts on which meshed gears are mounted

_____p. The circle from which the involute curve is generated

_____q. The portion of the tooth extending from the pitch circle to the tip

_____r. The distance between the tip of a gear tooth and the root of a gear tooth and the root of a mated gear.

_____s. The amount of overlap in two mating gear teeth.

_____t. The straight line distance across the gear tooth at the pitch circle, or the chord of the pitch circle arc cut by the gear tooth.

_____u. The common tangent to the base circle which passes through the pitch point of any pair of mating gears.

_____v. The angle between the line of action and the common tangent to the pitch circles at the pitch point

_____w. A ratio expressing the size of a gear tooth.

_____x. The English term used to denote tooth size

_____y. Another tooth modification used in power applications

_____z. The distance that some point on the pitch circle moves as the gear is rotated

21. Pitch Circle Displacement (S_p, S_g)
22. Pitch Circle Velocity (V_p, V_g)
23. Torque (T)
24. Hub
25. Hub Gear
26. Gear
27. Pitch Circle
28. Base Circle
29. Pressure Angle (ϕ)
30. Working Depth
31. Chordal Thickness
32. Fellows Stub Tooth
33. Module

TEST

_____aa. Distance traveled per unit of time

_____bb. The distance some point on the pitch circle moves per unit of time

_____cc. An instrument for measuring angular velocity

_____dd. The force acting through a distance.

_____ee. A unit of power equal to 33,000 ft-lbs per minute.

_____ff. Energy due to position such as height or strain.

_____gg. A force acting to cause rotation at some distance from a pivot point.

2. List five important techniques to be observed when using gears.

   1.
   2.
   3.
   4.
   5.

3. If the large gear is rotated clockwise, in which direction does the small gear turn?

4. Which of the two gears turns faster? Why?

5. Why is it important to have the gears and shafts properly mounted and aligned?

TEST

6. A certain gear measures 3.0625 inches OD and has 96 teeth. What is its pitch diameter?

7. A 68-tooth gear is meshed with a 30-tooth pinion. What is the center distance if the gear has an OD of 2.1875 inches and the pinion has an OD of 1.0 inch?

8. How would you figure the circular tooth thickness for a 42-tooth, 24-pitch gear? What is the thickness?

9. A Fellows Stub Tooth gear has a pitch of 5/7 and 24 teeth. What is the pitch diameter, outside diameter, addendum, dedendum, and clearance?

10. End of test - STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

TEST

STOP! Have your instructor evaluate your test. If additional study is required, ask your instructor about study requirements and possible retesting.

MATHEMATICAL EXPRESSIONS

$$D_o = 2R_o$$

$$C = R + r$$

$$C = \frac{D}{2} + \frac{d}{2}$$

$$C = \frac{D + 2}{2}$$

$$C = 1/2\,(D + d)$$

$$a = R_o - R$$

$$a = \frac{D_o}{2} - \frac{D}{2} = \frac{D_o - D}{2} = 1/2\,(D_o - D)$$

$$D = D_o \frac{N}{N + 2}$$

$$a = 1/2\left(D_o - D_o \frac{N}{N + 2}\right) = \frac{D_o}{2}\left(\frac{1 - N}{N + 2}\right)$$

$$a = \frac{D_o}{2}\left(\frac{N + 2}{N + 2} - \frac{N}{N + 2}\right) = \frac{D_o}{2}\left(\frac{2}{N + 2}\right) = \frac{D_o}{N + 2}$$

$$c = 0.157\,a$$

$$c = 0.157\,\frac{D_o}{N + 2}$$

$$b = a + c$$

$$b = \frac{D_o}{N + 2} + 0.157\,\frac{D_o}{N + 2} = 1.157\,\frac{D_o}{N + 2}$$

$$P_d = \frac{N}{D}$$

$$P_c = \frac{\pi}{P_d}$$

$$D = D_o \frac{N}{N + 2}$$

$$C = X - \frac{D_1}{2} - \frac{D_2}{2}$$

$$C = X - 1/2\,(D_1 + D_2)$$

$$C = X - d_s$$

$$\text{Module} = \frac{1}{P_d} D = D_o \frac{N}{N + 2}$$

$$\frac{N}{D} = \frac{N + 2}{D_o} = P_d$$

$$a = \frac{D_o}{N + 2} = \frac{1}{P_d}$$

$$b = 1.157\,\frac{D_o}{N + 2} = \frac{1.157}{P_d}$$

$$c = 0.157\,\frac{D_o}{N + 2} = \frac{0.157}{P_d}$$

$$a = \frac{0.8}{P_d},\ b = \frac{1}{P_d},\ c = \frac{0.2}{P_d}$$

$$a = \frac{1}{P},\ b = \frac{1.25}{P},\ c = \frac{0.25}{P}$$

$$a = R + r_o - c$$

MATHEMATICAL EXPRESSIONS

$$S_p = -S_g$$

$$\frac{S_p}{2\pi r} = \frac{\theta_p}{2\pi}$$

$$S_p = r\theta_p$$

$$S_g = R\theta_g$$

$$\theta_p = -R\theta_g$$

$$\frac{r}{R} = -\frac{\theta_g}{\theta_p}$$

$$-\frac{2r}{2R} = \frac{-\theta_g}{\theta_p}$$

$$\frac{d}{D} = -\frac{\theta_g}{\theta_p}$$

$$P_d = \frac{n}{d} = \frac{N}{D}$$

$$d = \frac{n}{P_d} \text{ and } D = \frac{N}{P_d}$$

$$\frac{n}{N} = \frac{-\theta_g}{\theta_p}$$

$$\frac{-\theta_g}{\theta_p} = \frac{n}{N} = \frac{d}{D}$$

$$S_p = -S_g$$

$$\frac{S_p}{T} = -\frac{S_g}{T}$$

$$V_p = -V_g$$

$$\omega = \frac{\theta}{t}$$

$$\frac{\theta_g}{\theta_p} = \frac{-d}{D}$$

$$\frac{\theta_{g/t}}{\theta_{p/t}} = \frac{-d}{D}$$

$$\frac{\omega_g}{\omega_p} = \frac{-d}{D}$$

$$\frac{\omega_g}{\omega_p} = \frac{-n}{N}$$

$$d = \frac{n}{P_d} \qquad D = \frac{N}{P_d}$$

$$v = \frac{N\omega}{60} \text{ teeth/sec.}$$

$$V = \frac{\pi D\omega}{60} \text{ in./sec.}$$

$$W = fs$$

$$P = \frac{W}{t} = \frac{fs}{t}$$

$$HP = \frac{\text{ft - lb/min}}{33{,}000}$$

$$PE = wh$$

$$KE = \frac{1}{2} m v^2$$

$$h = R_w\theta_g$$

$$wh = w R_w\theta_g$$

$$T = fr$$

$$W_g = T_g \theta_y$$

$$wR_w = f_g R$$

$$\frac{R_w}{R} = \frac{f_g}{w}$$

$$\frac{D_w}{D} = \frac{F_g}{w}$$

$$f_p = f_g$$

$$-T_p = f_p r$$

$$f_p = \frac{-T_p}{r}$$

$$\frac{-T_p}{r} = \frac{T_g}{R}$$

$$\frac{-T_p}{d} = \frac{T_g}{D}$$

$$T_g = f_g R$$

$$f_g = \frac{T_g}{R}$$

$$\frac{d}{D} = \frac{-T_p}{T_g}$$

$$\frac{n}{N} = \frac{-T_p}{T_g}$$

$$\frac{d_w}{d} = \frac{f_p}{f}$$

INTRODUCTION TO DRIVES

UNIT 1

ANSWERS TO ASSIGNMENT SHEET #1

1. Spur Gear - A disc wheel with involute teeth cut at 90° to its face.

2. Commercial Gears - A quality classification indicating large tolerances, thus permitting high volume production at low cost.

3. Precision Gears - Relatively high quality gears with smaller tolerance levels and higher cost than the commercial type.

4. Ultra-Precision Gears - Very high quality gears with close tolerances used in high precision instruments.

5. Hub Gear - A one piece gear and hub made from a single piece of material. Cost is relatively high because of excess material waste and machine time in making the hub.

6. Hubless Gear - A gear bored to accommodate a separate hub.

7. Hub - Material protruding from the side of a gear or pulley by which the gear is fastened to a shaft.

8. Staking - A method of fastening a hub to a gear in which the material in the hub is punched into the side of the gear.

9. Dutch Pinning - A method of attaching a hub to a gear by drilling a dowel hole at their union, perpendicular to the gear face (similar to a common kdyway), then pressing a dowel pin into the hole.

10. Split Hub - A hub which is split similar to a collet so that it may be clamped to hold onto a shaft.

11. Split Collet and Chuck - A device used to fasten a hubless gear to a shaft when frequent disassembly is necessary.

12. Bearings - Supports for shafts which will allow the shaft to turn with relatively little friction. Bearings may be of the sliding type, such as a sleeve or bushing; or a rolling type, as in ball or pin bearings, if it is important to minimize frictional losses.

13. Backlash - The play between the teeth of mated gears.

INTRODUCTION TO DRIVES

UNIT I

ANSWERS TO ASSIGNMENT SHEET #2

1. Outside Circle - A circle circumscribing the gear.
2. Outside Radius (R_O) - The radius of the "outside circle".
3. Outside Diameter (D_O) or (OD) - The diameter of the "outside circle".
4. Root Circle - A circle drawn around the base or roots of the gear teeth.
5. Root Radius (R_R) - The radius of the "root circle".
6. Root Diameter (D_R) - The diameter of the "root circle".
7. Pitch Circle - A circle indicating the effective size of the gear (between the root and outside circles).
8. Pitch Radius (R,r) - The radius of the pitch circle for the gear and pinion respectively.
9. Pitch Diameter (D,d) - The diameter of the pitch circle for the gear and pinion respectively.
10. Pinion - The smaller of two meshed gears (usually the driver).
11. Gear - The larger of two meshed gears when speaking of a gear and pinion.
12. Center Distance (C) - The distance between centers of two meshed gears. Center distance is equal to the sum of the pitch radii (R + r).
13. Tooth Count (N,n) - The number of teeth cut around the gear.
14. Shaft Diameter (d_s) - The diameter of a shaft.
15. Outside Shaft Spacing (X) - The distance between the outside of the shafts on which meshed gears are mounted.

INTRODUCTION TO DRIVES

UNIT I

ANSWERS TO ASSIGNMENT SHEET #3

1. Involute Curve - A spiraling curve, sections of which are commonly used in designing the outline of a gear tooth. An involute curve can be generated by tracing the path of a point on a taut string as the string is unwound from a circle or cylinder. Involute tooth design offers a strong tooth which will transmit uniform angular motion even if center distance is changed slightly.
2. Base Circle - The circle from which the involute curve is generated. The shape of the involute curve is totally dependent on the size of the base circle. For most gearing operations, the diameter of the base circle is equal to the desired pitch diameter times the cosine of teh pressure angle.
3. Tooth Face - The surface of the tooth that contacts a mating gear.
4. Addendum (a) - The portion of the tooth extending from the pitch circle to the tip.
5. Dedendum (d) - The portion of the gear tooth between the pitch circle and the root circle.
6. Clearance (c) - The distance between the tip of a gear tooth and the root of a gear tooth and the root of a mated gear. Clearance may also be defined as the difference between the dedendum and addendum. For American Standard full-depth involute teeth, the clearance has been standardized as 0.157 of the addendum.
7. Whole Depth - The distance from the top of a tooth to its root. Whole depth is equal to the addendum plus the dedendum.
8. Working Depth - The amount of overlap in two mating gear teeth. The working depth is equal to twice the addendum or the sum of the addendum and dedendum less the clearance.
9. Tooth Thickness (T) - The length of the arc measured along the pitch circle between opposite faces of a gear tooth.
10. Chordal Thickness - The straight line distance across the gear tooth at the pitch circle, or the chord of the pitch circle arc cut by the gear tooth.
11. Width - The distance across the face of a gear tooth.
12. Line of Action - The common tangent to the base circle which passes through the pitch point of any pair of mating gears.

ASSIGNMENT SHEET #3

13. Path of Contact - That portion of the line of action through which tooth contact takes place.

14. Pressure Angle (ϕ) - The angle between the line of action and the common tangent to the pitch circles at the pitch point.

15. Pitch - A term referring to the size of a gear tooth. Pitch may be expressed in several forms: diametral, circular, module, normal, etc.

16. Diametral Pitch (P, P_d or DP) - A ratio expressing the size of a gear tooth. Diametral pitch is equal to the number of teeth divided by the pitch diameter. In American Standard gears diametral pitch is always a whole number.

17. Circular Pitch (P_c) - The length of the arc along the pitch circle between the centers of two adjacent teeth. Circular pitch may also be thought of as the ratio of the pitch circumference to the number of teeth.

18. Module - The English term used to denote tooth size. Module is the pitch diameter divided by the number of teeth; hence, it is the reciprocal of diametral pitch. When module pitch is used without indication of units, it is assumed to be in metric measure.

19. 20-Degree Stub Involute - One of several modifications on full-depth involute tooth forms. The 20^0 stub system provides a stronger tooth for highly loaded gears without sacrificing a great deal of precision. This system is used for power applications in automotive and aircraft engines.

20. Fellows Stub Tooth - Another tooth modification used in power applications. Fellows stub gears drive machinery and are characterized as a powerful but sometimes noisy means of transmitting power.

INTRODUCTION TO DRIVES

UNIT I

ANSWERS TO ASSIGNMENT SHEET #4

Find the correct definitions for the following terms from Pages 25-42.

1. Pitch Point - The point of contact of the pitch circles when two gears are meshed.

2. Pitch Circle Displacement (Sp, Sg) - The distance that some point on the pitch circle moves as the gear is rotated. Pitch circle displacements are symbolized by S_p and S_g for the pinion and gear, respectively. The magnitudes of the displacements for two properly meshed gears are always equal, but the direction of displacement will be opposite. It is customary to assign a positive sign to clockwise motion and a negative sign to counterclockwise motion.

3. Angular Displacement (θ_p, θ_g) - The angle through which a gear rotates. As in pitch circle displacements, clockwise rotation is noted by a positive sign and counterclockwise rotation by a negative sign. It is shown algebraically that the angular displacement ratio between the pinion and gear is inversely proportional to their pitch radius, pitch diameter, and tooth count ratios.

4. Velocity - Distance traveled per unit of time.

5. Tooth Velocity - The number of teeth passing a given point per unit of time. Teeth per second is a common way to express pitch circle velocity.

6. Pitch Circle Velocity (V_p, V_g) - The distance some point on the pitch circle moves per unit of time. Pitch circle velocity may be expressed as a distance moved per unit of time, such as inches per second and feet per minute, or as the number of teeth passing a given point per unit time (teeth per second).

7. Angular Velocity (ω_p, ω_g) - An expression of how fast a body is turning. Angular velocity may be expressed in degrees per second, radians per second, revolutions per minute, etc.

8. Tachometer - An instrument for measuring angular velocity. Tachometers may be of several types such as mechanical, electrical, electronic, optical, nuclear, etc.

9. Stroboscope - A device for determining angular velocity by using a controlled flashing light.

10. Work (W) - The force acting through a distance.

ASSIGNMENT SHEET #4

11. Power (P) - The rate at which work is done.

12. Horsepower (HP) - A unit of power equal to 33,000 ft-lbs per minute.

13. Energy - The ability to do work.

14. Potential Energy (PE) - Energy due to position such as height or strain.

15. Kinetic Energy (KE) - Energy due to motion.

16. Torque (T) - A force acting to cause rotation at some distance from a pivot point.

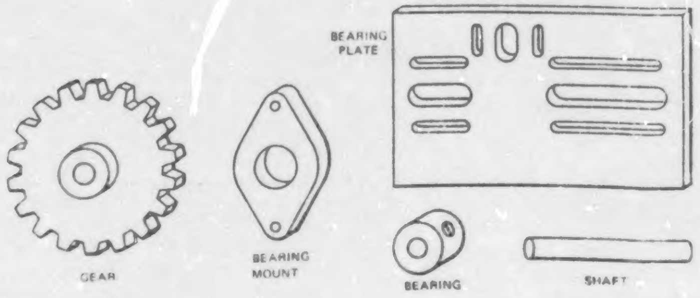
17. Radian - A unit used in measuring angles. An angle of one radian subtends an arc equal in length to the radius of the circule. (Displacement, θ, should be measured in radians.)

INTRODUCTION TO DRIVES

UNIT I

ANSWERS TO PROBLEMS - MECHANICAL COMPONENTS

1. Make a sketch of each component. Label each component.



2. Explain why it is possible to observe a tight spot when two gears are meshed.

   "Tight spots" may be the result of: burrs or a deformity in the gear teeth; nonconcentricity; noncircularity in the gear blank.

3. List five important techniques to be observed when using gears.

   (1) Mis-mesh gears so burrs do not hit.
   (2) Shafts must be parallel.
   (3) Shafts should be supported by two bearings.
   (4) Mount gear faces as close to bearings as possible.
   (5) Use gears made of dissimilar metals in high-speed situations.

4. Why is it considered good practice to mount gears close to the bearing supports?

   Gears should be mounted close to the bearing supports in order to help eliminate loading and misalignment of bearings.

5. If the large gear is rotated clockwise, in which direction does the small gear turn?

   Gears in direct-mesh rotat in opposite directions: therefore, if one gear rotates clockwise, the other gear in mesh rotates counterclockwise.

ANSWERS TO PROBLEMS - MECHANICAL COMPONENTS

6. Which of the two gears turns faster? Why?

   Since the gears must mesh tooth for tooth, the smaller gear must rotate faster than the larger gear. The ratio of these gear speeds will later be shown to be the same as their tooth ratio.

7. Why is it important to have the gears and shafts properly mounted and aligned?

   Improper mounting and misalignment will result in loss of efficiency in the gear train as well as undue damage and wear to the gears, shafts and bearings.

8. What might be some of the undesirable effects of using gears that are not properly meshed.

   Tight spots in the gear mesh may result in tooth damage as well as causing excessive frictional losses and strains on the shaft and bearings. A loose mesh shifts the gear load onto the ends of the gear teeth and increases backlash which will result in a jerky and noisy gear train.

INTRODUCTION TO DRIVES

UNIT I

ANSWERS TO PROBLEMS - GEAR DIAMETERS

1. A gear and pinion have 42 and 12 teeth respectively and OD's of 11 and 3.5 inches. What is the pitch diameter of each gear?

$$D = D_o \frac{N}{N+2} = (11) \frac{42}{42+2} = 10.5 \text{ in.}$$

$$d = d_o \frac{n}{n+2} = (3.5) \frac{12}{12+2} = 3 \text{ in.}$$

2. If you were going to mount the gear and pinion in problem 1 using 0.75 inch shafts, what center distance would you use?

$$C = 1/2\ (D + d) = 1/2\ (10.5 + 3) = 6.75 \text{ in.}$$

NOTE: Shaft diameter is not relevant in this problem.

3. A certain gear measures 3.0625 inches OD and has 96 teeth. What is its pitch diameter?

$$D = D_o \frac{N}{N+2} = 3.0625 \frac{96}{96+2} = 3 \text{ in.}$$

4. A 68-tooth gear is meshed with a 30-tooth pinion. What is the center distance if the gear has an OD of 2.1875 inches and the pinion has an OD of 1.0 inch?

$$D = D_o \frac{N}{N+2};\quad d = d_o \frac{n}{n+2}$$

$$C = 1/2\ (D + d) \quad \therefore C = 1/2 \left[D_o \frac{N}{N+2} + d_o \frac{n}{n+2}\right]$$

$$= 1/2 \left[(2.1875) \frac{68}{68+2} + (1.0) \frac{30}{30+2}\right] = 1.5315 \text{ in.}$$

INTRODUCTION TO DRIVES

UNIT I

ANSWERS TO PROBLEMS - GEAR TEETH

1. A certain gear has a pitch diameter of 5.0 in. and a diametral pitch of 8.

   (a) How many teeth does the gear have?

   $P_d = \frac{N}{D}$ so $N = P_d D = (8)(5) = 40$ teeth

   (b) What is the size of the addendum, dedendum, and clearance?

   $$a = \frac{1}{P_d} = \frac{1}{8} = 0.125 \text{ in.}$$

   $$b = \frac{1.157}{P_d} = \frac{1.157}{8} = 0.1445 \text{ in.}$$

   $$c = \frac{0.157}{P_d} = \frac{0.157}{8} = 0.0196 \text{ in.}$$

   (c) What is the OD of the gear?

   $$D_o = D\,\frac{N + 2}{N} = 5.25 \text{ in. or } D_o = \frac{N + 2}{P_d} = 5.25 \text{ in.}$$

2. Two 32-pitch gears have 60 and 85 teeth respectively. What are the pitch diameters, outside diameters, and whole tooth depth?

   $$D = \frac{N}{P_d} = \frac{85}{32} = 2.659 \text{ in.}$$

   $$d = \frac{n}{P_d} = \frac{60}{32} = 1.875 \text{ in.}$$

   $$D_o = \frac{N + 2}{P_d} = \frac{85 + 2}{32} = 2.72 \text{ in.}$$

   $$d_o = \frac{n + 2}{P_d} = \frac{60 + 2}{32} = 1.938 \text{ in.}$$

   $a = \frac{1}{P_d}$ $\qquad$ $b = \frac{1.157}{P_d}$

   Whole depth = a + b by definition

   $$\text{Whole depth} = \frac{1}{P_d} + \frac{1.157}{P_d} = \frac{2.157}{P_d} = \frac{2.157}{32} = 0.0674 \text{ in.}$$

ANSWERS TO PROBLEMS - GEAR TEETH

3. How would you figure the circular tooth thickness for a 42-tooth, 24-pitch gear? What is the thickness?

   The thickness (T) is equal to one-half of the circular pitch (P_c).

   Since $P_c = \frac{\pi D}{N} = \frac{\pi}{P_d}$, then $T = \frac{\pi}{2 P_d} = \frac{3.14}{2(24)} = 0.0655$ in.

4. A Fellows Stub Tooth gear has a pitch of 5/7 and 24 teeth. What is the pitch diameter, outside diameter, addendum, dedendum, and clearance?

   $D = \frac{N}{P} = \frac{24}{5} = 4.8$ in.

   $D_o = \frac{N + 2}{P} = \frac{24 + 2}{5} = 5.2$ in.

   For Fellows Stub design

   $a = \frac{1}{P} = \frac{1}{7} = 0.143$ in.

   $b = \frac{1.25}{P} = \frac{1.25}{7} = 0.1786$ in.

   $c = \frac{0.25}{P} = \frac{0.25}{7} = 0.0357$ in.

5. What would be the results in problem 1 if the gears were American Standard stub involute types?

   (a) $N = P_d D = (8)\ (5) = 40$ teeth

   (b) $a = \frac{0.8}{P_d} = \frac{0.8}{8} = 0.1$ in.

   $b. = \frac{1}{P_d} = 1/8 = 0.125$

   $c = \frac{0.2}{P_d} = \frac{.02}{8} = 0.025$ in.

   (c) $D_o = \frac{N + 2}{P_d} = \frac{40 + 2}{8} = 5.25$ in.

INTRODUCTION TO DRIVES

UNIT I

TEST ANSWERS

1. a. 5
b. 11
c. 25
d. 24
e. 13
f. 12
g. 4
h. 1
i. 15
j. 2
k. 27
l. 14
m. 26
n. 16
o. 3
p. 28
q. 17
r. 18
s. 30
t. 31
u. 19
v. 29
w. 20
x. 33
y. 32
z. 21
aa. 9
bb. 22
cc. 8
dd. 6
ee. 10
ff. 7
gg. 23

2. 1. Mis-mesh gears so burns do not hit.
2. Shafts must be parallel.
3. Shafts should be supported by two bearings.
4. Mount gear faces as close to bearings as possible.
5. Use gears made of dissimilar metals in high-speed situations.

3. Gears in direct-mesh rotate in opposite directions: therefore, if one gear rotates clockwise, the other gear in mesh rotates counterclockwise.

4. Since the gears must mesh tooth for tooth, the smaller gear must rotate faster than the larger gear. The ratio of these gear speeds will later be shown to be the same as their tooth ratio.

5. Improper mounting and misalignment will result in loss of efficiency in the gear train as well as undue damage and wear to the gears, shafts and bearings.

6. $D = D_o \frac{N}{N + 2} = 3.0625 \frac{96}{96 + 2} = 3$ in.

7. $D = D_o \frac{N}{N + 2}; \quad d = d_o \frac{n}{n + 2}$

$$C = 1/2\ (D + d) \quad \therefore \quad C = 1/2\ [D_o \frac{N}{N + 2} + d_o \frac{n}{n + 2}]$$

$$= 1/2[(2.1875) \frac{68}{68 + 2} + (1.0) \frac{30}{30 + 2}] = 1.5315 \text{ in.}$$

TEST ANSWERS

8. The thickness (T) is equal to one-half of the circular pitch (P_c).

Since $P_c = \frac{D}{N} = \frac{}{P_d}$, then $T = \frac{}{2P_d} = \frac{3.14}{2(24)} = 0.0655$ in.

9. $D = \frac{N}{P} = \frac{24}{5} = 4.8$ in.

$D_o = \frac{N + 2}{P} = \frac{24 + 2}{5} = 5.2$ in.

For Fellows Stub design

$a = \frac{1}{P} = \frac{1}{7} = 0.143$ in.

$b = \frac{1.25}{P} = \frac{1.25}{7} = 0.1786$ in.

$c = \frac{0.25}{P} = \frac{0.25}{7} = 0.0357$ in.

MECHANICAL DEVICES

UNIT II

GEARS

GEARS

UNIT II

OBJECTIVE

After completing this unit, the student should be able to calculate and observe quantities relating to simple and compound train, internal, helical and bevel gears. This knowledge will be shown by completing an assignment sheet, lab procedures, chapter problems and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit the student should be able to

1. Match terms associated with gears to their correct definitions.
2. Calculate quantities relating to simple trains.
3. Calculate quantities relating to compound trains.
4. Calculate quantities relating to internal gears.
5. Calculate quantities relating to helical gears.
6. Calculate quantities relating to bevel gears.
7. Demonstrate the ability to
    a. Observe and compute simple train quantities.
    b. Observe and compute compound train quantities.
    c. Observe and compute internal gear quantities.
    d. Observe and compute helical gear quantities.
    e. Observe and compute bevel gear quantities.

GEARS

UNIT II

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide procedure and Drives text.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss labs and problems from Drives.

   F. Demonstrate difference between simple and compound gears.

   G. Demonstrate uses of internal, helical, and bevel gears.

   H. Assist students in constructing and troubleshooting simple and compound gear train.

   I. Assist students in constructig and troubleshooting internal, helical, and bevel gear mechanism.

   J. Assist students in lab calculations.

   K. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheets.

   C. Take test.

GEARS

UNIT II

INSTRUCTIONAL MATERIAL

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheet.

   C. Test.

   D. Answers to assignment sheets.

   E. Answers to test.

II. References

   A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

   B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

   C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

   A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development, 1981.

GEARS

UNIT II

PROCEDURE SHEET

_____1. Study Simple Trains, "Drives", Pages 46-49.

_____2. Complete Assignment Sheet #1 using "Drives", Chapters 7, 8, 10, 12 and 13.

_____3. Do Lab Procedure, Simple Trains, "Drives", Pages 50-51.

_____4. Stop Have your instructor review your results. If necessary redo Steps 3 and 4.

_____5. Complete Problems, "Drives", Page 51.

_____6. Stop Have your instructor review your results. If the instructor is satisfied, continue to Step 7. Otherwise repeat Steps 1, 5 and 6.

_____7. Write An informal lab report for Simple Trains. Use he informal format discribed on "Drives", Page 207.

_____8. Study Compound Trains, "Drives", Pages 52-57.

_____9. Do Lab Procedure, "Drives", Pages 58-59.

____10. Stop Have your instructor review your results. If necessary redo Step 9.

____11. Complete Problems, "Drives", Page 60.

____12. Stop Have your instructor review your results. If the instructor is satisfied, continue to Step 13. Otherwise repeat Steps 8, 11 and 12.

____13. Write An Informal Lab Report for Compound Trains. Use the informal report format described on "Drives", Page 207.

____14. Study Internal Gear, "Drives", Pages 71-73.

____15. Do Lab Procedure, "Drives", Pages 71-73.

____16. Stop Have your instructor review your results. If necessary redo Steps 15 and 16.

____17. Complete Problems, "Drives", Page 73.

PROCEDURE SHEET

____18.	Stop	Have your instructor review your results. If your instructor is satisfied continue to Step 19. Otherwise repeat Steps 14, 17 and 18.
____19.	Write	An Informal Lab Report for Internal Gears.
____20.	Study	Helical Gears, "Drives", Pages 82-85.
____21.	Do	Lab Procedures, "Drives", Pages 86-88.
____22.	Stop	Have your instructor review your results. If necessary redo Steps 21 and 22.
____23.	Complete	Problems, "Drives", Page 88.
____24.	Stop	Have your instructor review your results. If the instructor is satisfied, continue to Step 25. Otherwise repeat Steps 20, 23 and 24.
____25.	Write	An Informal Lab Report for Helical Gears.
____26.	Study	Bevel Gears, "Drives", Pages 89-93.
____27.	Do	Lab Procedures, "Drives", Pages 93-95.
____28.	Stop	Have your instructor review your results. If necessary redo Steps 27 and 28.
____29.	Complete	Problems, "Drives", Page 96.
____30.	Stop	Have your instructor review your results. If the instructor is satisfied, continue to Step 31. Otherwise repeat Steps 26, 29 and 30.
____31.	Write	A formal Report for Bevel Gears. Use the format report described on "Drives", Pages 207-208.
____32.	Turn-In	All lab reports before continuing.
____33.	Review	Chapters 7, 8, 10, 12 and 13, "Drives".
____34.	Complete	Unit Test-Gears.
____35.	Stop	Have your instructor evaluate Unit Test - Gears. If your instructor is satisfied with your performance continue on to Unit III. Otherwise review the areas suggested by your instructor and repeat Steps 34 and 35.

GEARS

UNIT II

ASSIGNMENT SHEET #1 - TERMS ASSOCIATED WITH GEARS

Find the correct definitions for the following terms from Pages 17-34.

1. Simple Gear-train -
2. Idler -
3. Compound gear train -
4. Driver -
5. Driven gear or follower -
6. Internal or Annular Gears -
7. Inside Diameter (D_i) -
8. Helical Gear -
9. Contact Ratio -
10. Helix Angle (ψ) -
11. Normal Circular Pitch (P_{cn}) -
12. Normal Diametral Pitch (P_n) -
13. Side Thrust -
14. Herringbone Gears -
15. Bevel Gear -
16. External Toothed Bevel Gear -
17. Face or Crown Gear -
18. Internal Toothed Bevel Gear -
19. Zerol Gear -
20. Spiral Tooth Bevel Gears -
21. Hypoid Gears -
22. Cluster Gears -

GEARS

UNIT II
TEST

NAME ____ SCORE __________

1. Match terms associated with gears to their correct definitions. Place the correct number in the blank.

____a. A system of two or more gears arranged so that all tooth speeds are equal.

____b. A gear cut from a blank resembling a truncated cone.

____c. A gear wheel which drives another.

____d. The diameter of a circle inscribing an internal gear.

____e. The average number of teeth in contact when gear wheels are meshed.

____f. The angle at which helical teeth are cut across the gear blank.

____g. A bevel gear with a pitch angle.

____h. Two or more gear profiles cut from a single piece of stock.

____i. Double helical gears designed to eliminate side thrust.

____j. The trust load along the shaft axis, resulting from the force perpendicular to the line of contact on meshed gears.

____k. A gear wheel actuated by a driver.

____l. Bevel gears with curved teeth, similar to those on zerol gears, but the teeth do not radiate from the apex of the cone.

____m. A bevel gear with the teeth on the inside of a cone.

____n. Gears quite similar to spiral bevels in appearance, but the teeth are designed such that the axes of the mating gears do not intersect.

1. Idler
2. Bevel Gear
3. Contact Ratio
4. External Toothed Bevel Gear
5. Cluster Gears
6. Hypoid Gears
7. Zerol Gear
8. Helical Gear
9. Herringbone Gears
10. Inside Diameter (D_i)
11. Driver
12. Simple Gear-Train
13. Side Thrust
14. Normal Circular Pitch (P_{cn})
15. Internal or Annular Gears
16. Driven gear or follower
17. Normal Diametral Pitch (P_n)
18. Helix Angle (ψ)
19. Compound gear train

TEST

____o. A bevel gear with a pitch angle of 90° to the axis of rotation.

____p. The circular pitch measured perpendicular to the tooth line.

____q. The diametral pitch measured perpendicular to the tooth line.

____r. A gear with the same general blank form as a spur gear, but the teeth are cut at an angle to the axis of the shaft.

____s. Gears with their teeth formed inside the root circle.

____t. A system of gears in which two or more gears are mounted on a common shaft, thus requiring they have the same angular velocity.

____u. A gear between the input and output used to change center distance and direction of rotation of the output shaft.

____v. A bevel gear with a curved tooth, both ends of which lie on the same radial line.

20. Face or Crown Gear

21. Spiral Tooth Bevel Gears

22. Internal Toothed Bevel Gear

2. A 40-tooth, 32-pitch pinion is to be used to drive a 72-tooth gear with a center distance of 2.50 in. On a sheet of graph paper, show how you would locate a 95-tooth idler.

TEST

3. What is the value of the addendum, dedendum, and clearance of the gears in problem 5?

4. The input torque of the gear train in problem 5 is 245 in.-oz. What is the force acting on the teeth of each gear?

5. Four 48-pitch gears are used in a compound gear train. The input and output gears have 24 and 62 teeth respectively while the compound follower and driver have 70 and 36 teeth. What is the overall gear ratio of the train?

TEST

6. A 48-pitch pinion having 24 teeth is driving a 120-tooth internal gear. What is the center distance?

7. A 30-tooth R.H. helical pinion is meshed with a 72-tooth L.H. gear. The helix angle is 30^0 and the normal diametral pitch is 4. What is the diametral pitch?

8. Two meshing bevel gears have pitch angles of 31.75^0 and 13.25^0 respectively. What is the angle between the two shafts?

9. End of test - STOP. Have your instructor evaluate your test. If you received a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

GEARS

UNIT II

ANSWERS TO ASSIGNMENT SHEET #1

1. Simple Gear-train - A system of two or more gears arranged so that all tooth speeds are equal.

2. Idler - A gear between the input and output used to change center distance and direction of rotation of the output shaft.

3. Compound gear train - A system of gears in which two or more gears are mounted on a common shaft, thus requiring they have the same angular velocity.

4. Driver - A gear wheel which drives another.

5. Driven gear or follower - A gear wheel actuated by a driver.

6. Internal or Annular Gears - Gears with their teeth formed inside the root circle.

7. Inside Diameter (D_i) - The diameter of a circle inscribing an internal gear. The inside diameter is used in determining the pitch diameter of an internal gear in the same way as outside diameters are used when working with spur gears.

8. Helical Gear - A gear with the same general blank form as a spur gear, but the teeth are cut at an angle to the axis of the shaft.

9. Contact Ratio - The average number of teeth in contact when gear wheels are meshed.

10. Helix Angle (ψ) - The angle at which helical teeth are cut across the gear blank.

11. Normal Circular Pitch (P_{cn}) - The circular pitch measured perpendicular to the tooth line.

12. Normal Diametral Pitch (P_n) - The diametral pitch measured perpendicular to the tooth line.

13. Side Thrust - The trust load along the shaft axis, resulting from the force perpendicular to the line of contact on meshed gears.

14. Herringbone Gears - Double helical gears designed to eliminate side thrust.

15. Bevel Gear - A gear cut from a blank resembling a truncated cone. Although the tooth shapes may take several forms, the most common are cut straight, radiating from the apex of the pitch cone.

ANSWERS TO ASSIGNMENT SHEET #1

16. External Toothed Bevel Gear - A bevel gear with a pitch angle.

17. Face or Crown Gear - A bevel gear with a pitch angle of 90° to the axis of rotation.

18. Internal Toothed Bevel Gear - A bevel gear with the teeth on the inside of a cone. (Pitch angle greater than 90°)

19. Zerol Gear - A bevel gear with a curved tooth, both ends of which lie on the same radial line.

20. Spiral Tooth Bevel Gears - Bevel gears with curved teeth, similar to those on zerol gears, but the teeth do not radiate from the apex of the cone. Spiral gears offer some of the advantages generally associated with helical gears in that the teeth overlap, giving continuous pitch line contact.

21. Hypoid Gears - Gears quite similar to spiral bevels in appearance, but the teeth are designed such that the axes of the mating gears do not intersect.

22. Cluster Gears - Two or more gear profiles cut from a single piece of stock. These gears allow a single hub to be used for securing several compound gears.

GEARS

UNIT II

ANSWERS TO PROBLEMS - SIMPLE TRAINS

1. Four 48-pitch gears are arranged in a simple gear train. The input gear has 36 teeth. The two idlers have 44 each, and the output gear has 50 teeth. What is the speed and direction of the output gear if the input is turning 1800 RPM clockwise?

$$\omega 4 = -\frac{N_1}{N_4} \quad \omega 1 = -\frac{36}{50} \times 1800 = 1296 \text{ RPM counterclockwise}$$

2. All of the gears in problem 1 are mounted on 0.25 in. shafts. If the output torque is 270 in.-oz., what horsepower is being supplied to the input shaft? (Note: Assuming 100% efficiency, input and output power are equal.)

$$HP = \frac{T \times 2 \times \pi \times RPM}{12 \times 16 \times 33000} = \frac{270 \times 2 \times 3.14 \times 1296}{12 \times 16 \times 33000} = .347$$

3. If the train in problem 1 is assembled "on line", what is the center distance between input and output shafts?

$$D_1 = \frac{N_1}{P_d} = \frac{36}{48} = .75 \text{ in.} \quad R_1 = .375$$

$$D_2 = \frac{N_2}{P_d} = \frac{44}{48} = .917 \text{ in.}$$

$$D_3 = \frac{N_3}{P_d} = \frac{44}{48} = .917 \text{ in.}$$

$$D_4 = \frac{N_4}{P_d} = \frac{50}{48} = 1.04 \text{ inc.} \quad R_4 = .52$$

$$C = R_1 + D_2 + D_3 + D_4 = .375 + .917 + .917 + .52 = 2.729 \text{ in.}$$

4. What is the pitch circle velocity of the idler gears in problem 1? (Since the pitch circle velocity of all mesh gears is equal, values for input gears will be used.)

$$v = \frac{\pi D \omega}{60} = \frac{3.14 \times .75 \times 1800}{60} = 70.5 \text{ in./sec.}$$

ANSWERS TO PROBLEMS - SIMPLE TRAINS

5. A 40-tooth, 32-pitch pinion is to be used to drive a 72-tooth gear with a center distance of 2.50 in. On a sheet of graph paper, show how you would locate a 95-tooth idler.

$$D_p = \frac{N}{P_d} = \frac{40}{32} = 1.25 \text{ in.}$$

$$D_g = \frac{N}{P_d} = \frac{72}{32} = 2.25 \text{ in.}$$

$$D_i = \frac{N}{P_d} = \frac{95}{32} = 2.97 \text{ in.}$$

$R_p = .625$ in. $R_g = 1.125$ in. $R_i = 1.485$ in.

$C_p\text{-}i = .625 + 1.485 = 2.110$ in.

$C_g\text{-}i = 1.125 + 1.485 = 2.610$ in.

6. What is the value of the addendum, dedendum, and clearance of the gears in problem 5?

$$a = \frac{1}{P_d} = \frac{1}{32} = .03121 \text{ in.}$$

$$b = \frac{1.157}{P_d} = \frac{1.157}{32} = .0361 \text{ in}$$

$$c = \frac{0.157}{P_d} = \frac{0.157}{32} = .00491 \text{ in.}$$

7. The input torque of the gear train in problem 5 is 245 in.-oz. What is the force acting on the teeth of each gear?

$$f = \frac{T}{r} = \frac{245}{.625} = 392 \text{ oz.}$$

Equation 6.10 tells us the force on each gear is the same: $f_p = f_g$

8. If the output speed in problem 5 is 4000 RPM and all of the gears are mounted on 0.25 in. shafts, what is the input horsepower?

$$HP = \frac{f \times \pi \times D \times \omega}{12 \times 16 \times 33000} = \frac{392 \times 3.14 \times 2.25 \times 4000}{12 \times 16 \times 33000} = 1.75$$

GEARS

UNIT II

ANSWERS TO PROBLEMS - COMPOUND TRAINS

1. Four 48-pitch gears are used in a compound gear train. The input and output gears have 24 and 62 teeth respectively while the compound follower and driver have 70 and 36 teeth. What is the overall gear ratio of the train?

$$\text{gear ratio} = \frac{N_2 N_4}{N_1 N_3} = \frac{70 \text{ X } 62}{24 \text{ X } 36} = 5.05$$

2. If the gear train in problem 1 has all three shafts on the same center drive, what is the input/output center distance?

$$D_1 = \frac{N_1}{P_d} = \frac{24}{48} = .5 \text{ in.} \qquad D_3 = \frac{N_3}{P_d} = \frac{36}{48} = .75 \text{ in.}$$

$$D_2 = \frac{N_2}{P_d} = \frac{70}{48} = 1.46 \text{ in.} \qquad D_4 = \frac{N_4}{P_d} = \frac{62}{48} = 1.29 \text{ in.}$$

$$R = \frac{D}{2} \quad R_1 = .25 \text{ in.} \quad R_2 = .73 \text{ in.} \quad R_3 = .375 \text{ in.} \quad R_4 = .645 \text{ in.}$$

$$C = R_1 + R_2 + R_3 + R_4 = .25 + .73 + .375 + .645 = 2.00 \text{ in.}$$

3. If the input shaft in problem 1 turns at 3500 RPM, what is the angular velocity of each of the gears?

$$\omega_2 = -\omega_1 \frac{N_1}{N_2} = -3500 \text{ X } \frac{24}{70} = -1200 \text{ RPM}$$

$$\omega_2 = \omega_3 = -1200 \text{ RPM}$$

$$\omega_4 - \omega_1 \frac{N_1 N_3}{N_2 N_4} = 3500 \text{ X } \frac{24 \text{ X } 36}{70 \text{ X } 62} = 695 \text{ RPM}$$

4. If the gear train in problem 1 has an output speed of 200 RPM and an output shaft torque of 460 in.-oz., what is the input power? (Give answer in HP) (Assuming 100% efficiency, output and input powers are equal.)

$$HP = \frac{2T \ \pi \ \omega}{12 \text{ X } 16 \text{ X } 33{,}000} = \frac{2 \text{ X } 460 \text{ X } 3.14 \text{ X } 200}{12 \text{ X } 16 \text{ X } 33{,}000} = .0912$$

ANSWERS TO PROBLEMS - COMPOUND TRAINS

5. The gear train in figure 8.4 uses five pitch gears having tooth counts of:

$N_1 = 24 \quad N_2 = 80 \quad N_3 = 26 \quad N_4 = 72 \quad N_5 = 24 \quad N_6 = 95$

What is the output shaft speed if the input turns 4800 RPM?

$$\omega_6 = \omega_1 \frac{N_1 N_3 N_5}{N_2 N_4 N_6} = 4800 \times \frac{24 \times 26 \times 24}{80 \times 72 \times 95} = 131.4 \text{ RPM}$$

6. If the output torque in problem 5 is 290 ft-lb, what is the horsepower that is being delivered to the input shaft?

$$HP = \frac{2 T \pi \omega}{33{,}000} = \frac{2 \times 290 \times 3.14 \times 131.4}{33{,}000} = 7.26$$

GEARS

UNIT II

ANSWERS TO PROBLEMS - INTERNAL GEARS

1. A 48- pitch pinion having 24 teeth is driving a 120-tooth internal gear. What is the center distance?

$$C = \frac{N - n}{2P_d} = \frac{120 - 24}{2 \times 48} = 1 \text{ in.}$$

2. If the pinion in problem 1 is turning 3800 RPM, how fast is the internal gear turning?

$$\omega_g = \omega_p \frac{n}{N} = 3800 \times \frac{24}{120} = 760 \text{ RPM}$$

3. What is the tooth velocity in problem 2?

$$v_g = \frac{N \omega_g}{60} = \frac{120 \times 760}{60} = 1520 \text{ teeth-per-second}$$

$$v_p = \frac{n \omega_p}{60} = \frac{24 \times 3800}{60} = 1520 \text{ teeth-per-second}$$

4. What is the ID of the internal gear in problem 1?

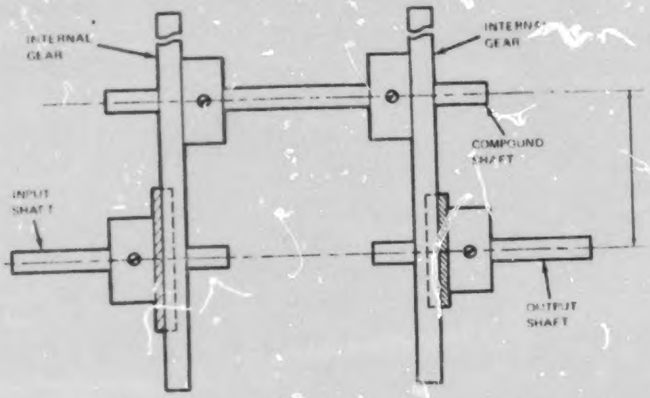
$$D = \frac{N}{P_d} = \frac{120}{48} = 2.5 \text{ in.} \qquad D_i = D\frac{N - 2}{N} = 2.5 \times \frac{120 - 2}{120} = 2.45 \text{ in.}$$

5. If the internal gear shaft in problem 2 is producing 40 ft.-lb. of torque, what is the power (in HP) applied to the pinion shaft? .

$$HP = \frac{2T \pi \omega}{33{,}000} = \frac{2 \times 40 \times 3.14 \times 760}{33{,}000} = 5.79$$

ANSWERS TO PROBLEMS - INTERNAL GEARS

6. Make a sketch showing how two internal gears and two pinions can be arranged into a reverted gear train.


INTERNAL GEAR
INTERNAL GEAR
COMPOUND SHAFT
INPUT SHAFT
OUTPUT SHAFT

GEARS

UNIT II

ANSWERS TO PROBLEMS - HELICAL GEARS

1. A 30-tooth R.H. helical pinion is meshed with a 72-tooth L.H. gear. The helix angle is 30° and the normal diametral pitch is 4. What is the diametral pitch?

$$P_d = P_n \cos\psi = 4 \cos 30^{\circ} = 3.464 \text{ in.}$$

2. What is the circular pitch of the gears in problem 1?

$$P_c = \frac{\pi}{P_n \cos \psi} = \frac{3.14}{4 \cos 30^{\circ}} = .906 \text{ in.}$$

3. What is the normal circular pitch in problem 1?

$$P_{cn} = \frac{\pi}{P_n} = \frac{3.14}{4} = .785 \text{ in.}$$

4. What should be the minimum tooth width in problem 1?

$$= \frac{P_c}{\tan\psi} = \frac{.906}{\tan 30^{\circ}} = 1.57 \text{ in.}$$

5. If the gear in problem 1 turns 75° clockwise, through what angle will the pinion rotate?

$$\theta_p = -\theta_g \frac{N}{n} = -75^{\circ} \times \frac{72}{30} = -180^{\circ}$$

$$\theta_p = 180^{\circ} \text{ counterclockwise}$$

6. What is the velocity ratio in problem 1?

$$\frac{\omega_g}{\omega_p} = -\frac{n}{N} = -\frac{30}{72} = -.416$$

7. If 940 in.-lb. of torque is transmitted by the gear in problem 1, what is the side thrust?

$$D = \frac{P_c N}{\pi} = \frac{.906 \times 72}{3.14} = 20.7 \text{ in.}$$

$$f_y = \frac{2T}{D} \tan\psi = \frac{2 \times 940}{20.7} \tan 30^{\circ} = 52.14 \text{ lbs.}$$

ANSWERS TO PROBLEMS - HELICAL GEARS

8. In problem 7 what torque is transmitted by the pinion?

$$T_p = -T_g\frac{n}{N} = -940\frac{30}{72} = -392 \text{ in.-lbs.}$$

GEARS

UNIT II

ANSWERS TO PROBLEMS - BEVEL GEARS

1. A 48-pitch bevel gear has 45 teeth. What is the pitch diameter?

$$D = \frac{N}{P_d} = \frac{45}{48} = .938 \text{ in.}$$

2. The gear in problem 1 is to mesh with a 30-tooth pinion. What is the gear ratio?

$$\text{gear ratio} = \frac{n}{N} = \frac{30}{45} = .667 \text{ or } 2:3$$

3. What is the pitch diameter of the pinion in problem 2?

$$d = \frac{n}{P_d} = \frac{30}{48} = .625 \text{ in.}$$

4. The gears in problem 2 are to be used with shafts 90° apart. What is the pitch angle of each gear?

$$\alpha = \tan^{-1} \frac{\sin \gamma}{\left(\frac{d}{D} + \cos\gamma\right)} = \tan^{-1} \frac{\sin 90^\circ}{\left(\frac{.625}{.938} + \cos 90^\circ\right)} = 56^\circ$$

$$\beta = \gamma - \alpha = 90^\circ - 56^\circ = 34^\circ$$

5. Two meshing bevel gears have pitch angles of 31.75° and 13.25° respectively. What is the angle between the two shafts?

$$\gamma = \alpha + \beta = 31.75^\circ + 13.25^\circ = 45^\circ$$

6. A 72-pitch bevel gear set is to be used between shafts that are 30° apart. The velocity ratio is to be 1:3. Specify pitch angles and tooth counts for the gears.

$$\alpha = \tan^{-1} \frac{\sin \gamma}{\left(\frac{d}{D} + \cos\gamma\right)} = \tan^{-1}\left(\frac{\sin 30^\circ}{1/3 + \cos 30^\circ}\right) = \tan^{-1} .417 = 22^\circ$$

$$\beta = \gamma - \alpha = 30^\circ - 22^\circ = 8^\circ$$

Since the tooth count ratio is equal to the velocity ratio any tooth count that is in the ratio 1:3 is acceptable. For example: n = 24 teeth; N = 72 teeth.

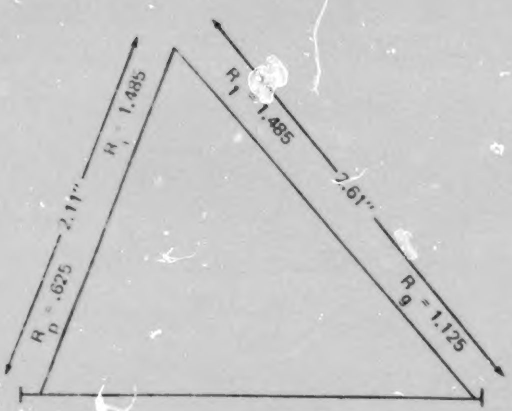
GEARS

UNIT II

TEST ANSWERS

1. a. 12
   b. 2
   c. 11
   d. 10
   e. 3
   f. 18
   g. 4
   h. 5
   i. 9
   j. 13
   k. 16
   l. 21
   m. 22
   n. 6
   o. 20
   p. 14
   q. 17
   r. 8
   s. 15
   t. 19
   u. 1

2.



$D_p = \frac{N}{P_d} = \frac{40}{32} = 1.25$ in.

$D_g = \frac{N}{P_d} = \frac{72}{32} = 2.25$ in.

$D_i = \frac{N}{P_d} = \frac{95}{32} = 2.97$ in.

$R_p = .625$ in. $R_g = 1.125$ in. $R_i = 1.485$ in.

$C_p\text{-}i = .625 + 1.485 = 2.110$ in.

$C_g\text{-}i = 1.125 + 1.485 = 2.610$ in.

3. $a = \frac{1}{P_d} = \frac{1}{32} = .03121$ in.

$b = \frac{1.157}{P_d} = \frac{1.157}{32} = .0361$ in.

$c = \frac{0.157}{P_d} = \frac{0.157}{32} = .00491$

TEST ANSWERS

4. $f = \frac{T}{r} = \frac{245}{.625} = 392$ oz.

5. gear ratio = $\frac{N_2 \; N_4}{N_1 \; N_3} = \frac{70 \times 62}{24 \times 36} = 5.05$

6. $C = \frac{N - n}{2 \, P_d} = \frac{120 - 24}{2 \times 48} = 1$ in.

7. $P_d = P_n \cos \psi = 4 \cos 30^\circ = 3.464$ in.

8. $\gamma = \alpha + \beta = 31.75^\circ + 13.25^\circ = 45^\circ$

MECHANICAL DEVICES

UNIT III

MECHANISMS

MECHANISMS

UNIT III

OBJECTIVE

After completing this unit, the student should be able to calculate and observe characteristics of rack-and-pinion, worm-and-wheel, combined and differential mechanisms. This knowledge will be shown by completing assignment sheet, lab report, lab problems and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with mechanisms to their correct definition.
2. Solve problems relating to rack-and-pinion mechanisms.
3. Calculate input torque for a worm-and-wheel mechanism.
4. List three applications of worm-and-wheel mechanisms.
5. Calculate the torque in combined mechanisms.
6. Discuss the operation of a counter rotator.
7. List practical applications for mechanical differentials.
8. Sketch a differential mechanism that has two outputs in line with each other from a single input at right angles to the outputs.
9. Demonstrate the ability to
    - a. Construct rack-and-pinion mechanisms.
    - b. Examine operating characteristics of a worm-and-wheel mechanism.
    - c. Construct combined mechanisms.
    - d. Examine torque and displacement ratios for counter rotation.
    - e. Examine operating characteristics of a differential mechanism.

MECHANISMS

UNIT III

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.

  B. Provide students with procedure sheet and Drives Text.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss labs and problems from Drives.

  F. Demonstrate various mechanical configurations.

  G. Discuss application of mechanical differentials.

  H. Assist students in constructing and troubleshooting of mechanism.

  I. Assist students in lab calculations.

  J. Give test.

II. Student

  A. Read objective sheet.

  B. Complete procedure sheets.

  C. Take test.

MECHANISMS

UNIT III

INSTRUCTIONAL MATERIAL

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheet.

   C. Test.

   D. Answers to assignment sheets.

   E. Answers to test.

II. References

   A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

   B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

   C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

   A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development, 1981.

MECHANISMS

UNIT III

PROCEDURE SHEET

_____1. Complete Assignment Sheet #1 using Experiments 14, 15, 17, 18 and 19, "Drives", Pages 96-131.

_____2. Study Rack and Pinion, "Drives", Pages 96-98.

_____3. Do Lab Procedures, Rack and Pinion, Pages 98-101.

_____4. Stop Have your instructor review your results. If necessary redo Step 3.

_____5. Complete Problems, "Drives", Pages 101-102.

_____6. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 7. Otherwise repeat Steps 2, 5 and 6.

_____7. Write An informal lab report for Rack and Pinion. Use the informal format described on Page 207, "Drives".

_____8. Study Worm and Wheel, "Drives", Pages 103-105.

_____9. Do Lab Procedure, Worm and Wheel, Pages 106-107.

_____10. Stop Have your instructor review your results. If necessary redo Step 9.

_____11. Complete Problems, "Drives", Page 107.

_____12. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 13. Otherwise repeat Steps 8, 11 and 12.

_____13. Write An informal lab report for Worm and Wheel. Use the informal format described on Page 207, "Drives".

_____14. Study Combined Mechanisms, "Drives", Pages 114-118.

_____15. Do Lab Procedures, "Drives", Pages 119-121.

_____16. Stop Have your instructor review your results. If necessary redo Step 15.

_____17. Complete Problem, "Drives", Page 121.

PROCEDURE SHEET

____18.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 19. Otherwise repeat Steps 14, 17 and 18.
____19.	Write	An informal lab report for Combined Mechanisms. Use the informal format described on Page 207, "Drives".
____20.	Study	Counter Rotators, "Drives", Pages 122-124.
____21.	Do	Lab Procedures, "Drives", Pages 125-127.
____22.	Stop	Have your instructor review your results. If necessary redo Step 21.
____23.	Complete	Problems, "Drives", Page 127.
____24.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 25. Otherwise repeat Steps 20, 23 and 24.
____25.	Write	An informal lab report for Counter Rotators. Use the informal format described on Page 207, "Drives".
____26.	Study	Mechanical Differentials, "Drives", Pages 128-131.
____27.	Do	Lab Procedures, "Drives", Pages 132-135.
____28.	Stop	Have your instructor review your results. If necessary redo Step 27.
____29.	Complete	Problems, "Drives", Page 135.
____30.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 31. Otherwise repeat Steps 26, 29 and 30.
____31.	Write	An informal lab report for Mechanical Differentials. Use the informal format described on Page 207, "Drives".
____32.	Turn-In	All lab reports before continuing.
____33.	Review	Chapters 14, 15, 17, 18 and 19, "Drives".

PROCEDURE SHEET

____34. Complete Unit Test - Mechanisms.

____35. Stop Have your instructor evaluate the Unit Test - Mechanisms. If your instructor is satisfied with your performance, continue on to Unit IV. Otherwise review the areas suggested by your instructor and repeat Steps 34 and 35.

MECHANISMS

UNIT III

ASSIGNMENT SHEET #1 - TERMS AND DEFINITIONS ASSOCIATED WITH MECHANISMS

Using Pages 96-131 of "Drives", write the correct definition after each term.

1. Rack -
2. Worm -
3. Worm Wheel -
4. Efficiency (N_0) -
5. Static Torque -
6. Running Torque -
7. Prony Brake -
8. Counter Rotator -
9. Differential -
10. Spider Shaft -
11. Spider Gear -
12. Cross Shaft -
13. Junction Block -
14. Balance Block -

MECHANISMS

UNIT III
TEST

NAME____ SCORE__________

Use the Mathematical Expression Sheet, included with the test, and work the problems.

1. Match terms associated with mechanisms to their correct difinitions. Place the correct number in the blank.

_____a. Material positioned on the cross shaft opposite the spider gear to balance the weight about the axis of the spider shaft.

_____b. Is usually thought of as an array of gears producing an output proportional to the difference between two inputs.

_____c. Torque measured when mechanism is in motion.

_____d. A mechanical array providing for two in line output shafts rotating in opposite directions.

_____e. A bevel or crown gear mounted on, but not fixed to, the cross shaft.

_____f. A connection providing for the right angle union of the cross shaft and spider shaft.

_____g. A straight length of tooth gearing.

_____h. The ratio of the output to input work.

_____i. A form of helical gear consisting of a continuous screw thread or threads cut around a cylinder.

_____j. Commonly the output shaft of a mechanical differential assembly.

_____k. A shaft intersecting the spider shaft at right angles.

_____l. A gear usually driven by the worm.

_____m. Torque measured when mechanism is at rest.

_____n. A device for loading a mechanism by letting it run against some sort of friction brake.

1. Rack
2. Balance Block
3. Worm
4. Junction Block
5. Worm Wheel
6. Efficiency (N_0)
7. Cross Shaft
8. Spider Gear
9. Static Torque
10. Running Torque
11. Spider Shaft
12. Prony Brake
13. Differential
14. Counter Rotator

TEST

2. Show your work for the following rack-and-pinion problems.

   A. An automobile has a rack-and-pinion steering mechanism. The rack is 9 in. long and the pinion has 24 teeth. The pinion has a pitch of 12. How far does the rack move per pinion revolution?

   B. If the feed wheel arms are 6 inches long with diameter of 1.5 inches and the operator applies 15 lbs. of force to them, what is the force on the bit?

TEST

3. Show your work for the following worm-and-wheel problem.

A double threaded worm drives a 110-tooth wheel, and the mechanism has an efficiency of 65 percent. If the output torque is 260 in.-oz., what is the input torque?

4. List at least three practical applications of a worm-and-wheel mechanisms.

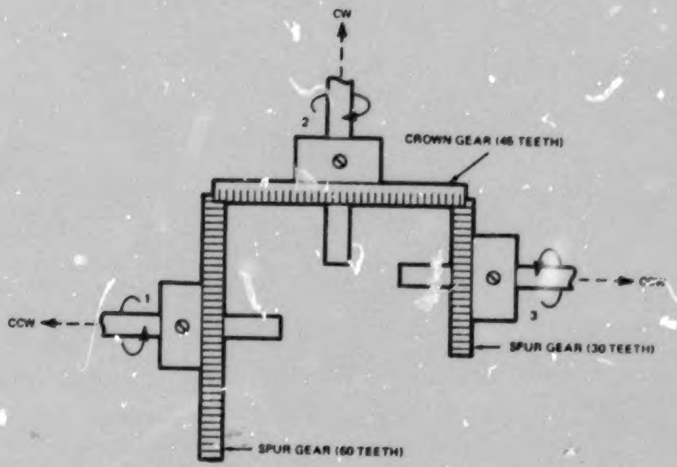
5. Show your work for the following Combined Mechanisms problem.

If a block in a Combined Mechanism were driving a 200 ounce load and the pitch of the single lead screw is 0.050 in., what would be the torque in the screw? (NOTE: assume 100% efficiency.)

TEST

6. Discuss the operation of the Counter Rotator shown in figure 1.

FIGURE 1


CW
2
CROWN GEAR (45 TEETH)
1
CCW
CCW
3
SPUR GEAR (30 TEETH)
SPUR GEAR (60 TEETH)

7. List six applications for differential mechanisms.

a.

b.

c.

d.

e.

f.

TEST

8. Make a sketch showing how a Differential Mechanism is used in an automobile rear end.

9. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

MATHEMATICAL EXPRESSIONS

$$S = r\,\theta_p$$

$$S_r = 1/2\,d\,\theta_p$$

$$S_r = \pi d \text{ in. per rev.}$$

$$v_r = \pi\omega d \text{ in. per min.}$$

$$v_r = 1/60\,\pi\omega d \text{ in. per sec.}$$

$$v_r = 0.0525\,\omega d \text{ in. per sec.}$$

$$N = \frac{\omega_w}{\omega_g} = \frac{\theta_w}{\theta_g}$$

$$\eta_o = 100\frac{W_o}{W_i} \text{ Percent}$$

$$W_o = T_g\,\theta_g$$

$$W_i = T_w\,\theta_w$$

$$\eta_o = 100\frac{T_g\,\theta_g}{T_w\,\theta_w} \text{ Percent}$$

$$\frac{\theta_w}{\theta_g} = N_g$$

$$\theta_2 = -\theta_1\,\frac{N_1}{N_2}$$

$$\theta_3 = \theta_2 = -\theta_1\,\frac{N_1}{N_2}$$

$$\theta_4 = -\theta_3\,\frac{N_3}{N_4}$$

$$\theta_4 = \theta_1\,\frac{N_1\,N_3}{N_2\,N_4}$$

$$S_r = (1/2)D_4\,\theta_4$$

$$\omega = \frac{v_r}{0.0525d} = 19.1\,\frac{v_r}{d} \text{ RPM}$$

$$W_r = f_r\,S_r$$

$$W_p = T_p\,\theta_p$$

$$T_p\,\theta_p = f_r\,S_r$$

$$T_p\,\theta_p = 1/2\,f_r\,d\theta_p$$

$$T_p = 1/2\,f_r\,d$$

$$f_r = 2\,\frac{T_p}{d}$$

$$\eta_o = 100\,\frac{T_g}{N_g T_w} \text{ percent}$$

$$\eta = \frac{T_g}{N_g T_w}$$

$$N_g = \frac{\omega_w}{\omega_g} = \frac{\theta_w}{\theta_g} = \frac{1}{\eta}\,\frac{T_g}{T_w}$$

$$\frac{N_g}{K} = \frac{\omega_w}{\omega_g} = \frac{\theta_w}{\theta_g} = \frac{1}{\eta}\,\frac{T_g}{T_w}$$

$$S_r = 1/2\,D_4\,\theta_1\,\frac{N_1\,N_3}{N_2\,N_4}$$

$$T_4 = 1/2\,D_4\,f_r$$

$$T_3 = -T_4\,\frac{N_3}{N_4} = -1/2\,D_4\,f_r\,\frac{N_3}{N_4}$$

$$T_2 = T_3 = -1/2\,D_4 f_r\,\frac{N_3}{N_4}$$

$$T_1 = 1\,T_2\,\frac{N_1}{N_2} = (1/2)\,D_4 f_r\,\frac{N_1\,N_3}{N_2\,N_4} \text{ in.-oz}$$

MATHEMATICAL EXPRESSIONS

$$\frac{n}{N} = -\frac{\theta_g}{\theta_p} = -\frac{\omega_g}{\omega_p} = -\frac{T_p}{T_g} = \frac{d}{D}$$

$$\frac{N_1}{N_3} = -\frac{\theta_3}{\theta_1} = -\frac{\omega_3}{\omega_1} = \frac{D_1}{D_3}$$

$$\frac{N_2}{N_3} = -\frac{\theta_3}{\theta_2} = -\frac{\omega_3}{\omega_2} = \frac{D_2}{D_3}$$

$$N_3 = -N_1 \frac{\theta_1}{\theta_3} \text{ and } N_3 = -N_2 \frac{\theta_2}{\theta_3}$$

$$N_1 \theta_1 = N_2 \theta_2$$

$$\frac{N_1}{N_2} = \frac{\theta_2}{\theta_1}$$

$$\frac{N_1}{N_2} = \frac{\theta_2}{\theta_1} = \frac{\omega_2}{\omega_1} = \frac{D_1}{D_2}$$

$$\theta_1 = 2\theta_s \text{ if } \theta_2 = 0$$

$$\theta_s = (1/2)\,\theta_1 \text{ if } \theta_2 = 0$$

$$\theta_s = (1/2)\,\theta_2 \text{ if } \theta_1 = 0$$

$$\theta_s = (1/2)\,\theta_1 + (1/2)\,\theta_2$$

$$\theta_s = (1/2)\,(\theta_1 + \theta_2)$$

$$\frac{\theta_s}{t} = (1/2)\,\frac{\theta_1}{t} + (1/2)\,\frac{\theta_2}{t}$$

$$\omega_s = (1/2)\,\omega_1 + (1/2)\,\omega_2$$

$$T_1 = (1/2)\, f_1 D_1$$

$$f_1 = 2\,\frac{T_1}{D_1}$$

$$f_2 = 2\,\frac{T_2}{D_2}$$

$$f_3 = f_1 + f_2 = 2\left(\frac{T_1}{D_1} + \frac{T_2}{D_2}\right)$$

$$f_3 = 2\,\frac{T_3}{D_3}$$

$$\frac{T_3}{D_3} = \frac{T_1}{D_1} - \frac{T_2}{D_2}$$

$$\frac{T_1}{D_1} = \frac{T_3}{D_3} + \frac{T_2}{D_2}$$

$$\omega_s = (1/2)\,(\omega_1 + \omega_2)$$

$$f_1 = \frac{T_1}{r_1} \text{ and } f_2 = \frac{T_2}{r_2}$$

$$f_1 = 2\,\frac{T_1}{D} \text{ and } f_2 = 2\,\frac{T_2}{D}$$

$$f_s = f_1 + f_2 = \frac{2}{D}(T_1 + T_2)$$

$$r_s = r_1 = r_2 = (1/2)\,D$$

$$T_s = f_s r_s = f_s \frac{D}{2}$$

$$T_s = T_1 + T_2$$

MECHANISMS

UNIT III

ANSWERS TO ASSIGNMENT SHEET #1

1. Rack - A straight length of tooth gearing. A rack may be compared to a gear of infinite diameter.

2. Worm - A form of helical gear consisting of a continuous screw thread or threads cut around a cylinder.

3. Worm Wheel - The gear usually driven by the worm. The gear teeth are often helical and concave to fit the curvature of the worm.

4. Efficiency (N_0) - The ratio of the output to input work.

5. Static Torque - Torque measured when mechanism is at rest.

6. Running Torque - Torque measured when mechanism is in motion.

7. Prony Brake - A device for loading a mechanism by letting it run against some sort of friction brake.

8. Counter Rotator - A mechanical array providing for two inline output shafts rotating in opposite directions.

9. Differential - Is usually thought of as an array of gears producing an output proportional to the difference between two inputs. This condition may be reversed, however, as in an automotive rear end.

10. Spider Shaft - Commonly the output shaft of a mechanical differential assembly. The input gears are mounted on, but not fixed to, the spider shaft.

11. Spider Gear - A bevel or crown gear mounted on, but not fixed to, the cross shaft. The spider gear transmits torque from the two inputs to the spider shaft.

12. Cross Shaft - A shaft intersecting the spider shaft at right angles. The cross shaft serves as a connection between the spider gear and spider shaft.

13. Junction Block - A connection providing for the right angle union of the cross shaft and spider shaft.

14. Balance Block - Material positioned on the cross shaft opposite the spider gear to balance the weight about the axis of the spider shaft. The balance block is sometimes replaced by a second spider gear.

MECHANISMS

UNIT III

ANSWERS TO PROBLEMS - RACK AND PINION

1. An automobile has a rack-and-pinion steering mechanism. The rack is 9 in. long and the pinion has 28 teeth. The pinion has a pitch of 14. How far does the rack move per pinion revolution?

$$d = \frac{n}{P_d} = \frac{28}{14} = 2 \text{ in.}$$

$$S_r = \pi d = 3.1416 \times 2 = 6.2832 \text{ in.}$$

2. In problem 1, how many pinion revolutions are required to move the rack from end to end?

$$\text{pinion rev.} = \frac{\text{max. } S_r}{S_r} = \frac{9}{6.28} = 1.43 \text{ revolutions}$$

3. The steering wheel in the car above must be turned approximately 2.8 turns to move the rack from end to end. What is the gear ratio between the steering wheel and the pinion?

$$\text{gear ration} = \frac{\text{steering wheel revolutions}}{\text{pinion revolutions}} = \frac{2.8}{1.4} = 2:1$$

4. How many teeth are there on the rack in problem 1?

$$N_r = \text{number of pinion rev.} \times n_p = 1.43 \times 28 = 40 \text{ teeth}$$

5. The steering wheel in problem 3 has a 12-in diameter. When the car is standing still, the driver must exert 14 pounds of force on the steering wheel to move the rack. What is the rack force?

$$T = fr$$

$$T_{sw} = 14 \times 6 = 84 \text{ in.-lbs.}$$

$$T_p = (\text{g.r.})\, T_{sw} = 2 \times 84 = 168 \text{ in.-lbs.}$$

$$\frac{r_g}{r_p} = \text{g.r.} = \frac{6}{2} = 3 \text{ in.}$$

ANSWERS TO PROBLEMS - RACK AND PINION

$d_p = 6$ in.

$$f_r = 2 \frac{T_p}{d} = 2 \times \frac{168}{6} = 56 \text{ lbs}$$

6. A drill press uses a rack-and-pinion between the feed wheel and the quill. The pinion is 24 pitch and has 36 teeth. How long must the rack be if the feed wheel turns 1-1/2 times to move the quill from its highest to its lowest position?

$$d = \frac{n}{P_d} = \frac{36}{24} = 1.5 \text{ in.}$$

$$S_r = \pi d = 3.14 \times 1.5 = 4.71 \text{ in. per rev.}$$

$$\text{(in. 1-1/2 rev.) } S = S_r \times 1.5 = 7.07 \text{ in.}$$

7. How fast must the feed wheel turn to move the bit 2 in. per min.?

$$\omega = \frac{v_r}{d} = \frac{2}{3.14 \times 1.5} = .425 \text{ RPM}$$

8. If the feed wheel arms are 8 inches long and the operator applies 30 lbs. of force to them, what is the force on the bit?

$$T_p = f_p r = 30 \times 8 = 240 \text{ in.-lbs.}$$

$$f_r = 2 \frac{T_p}{d} = 2 \times \frac{240}{1.5} = 320 \text{ lbs}$$

9. The frill press in figure 14-7 has a return spring which retracts the quill to its highest position when the feed wheel is released. This spring exerts 4 lbs. of force upward on the quill. How much torque must the operator apply to the pinion to overcome the spring?

$$T_p = 1/2 \, f_r \, d = 1/2 \times 4 \times 1.5 = 3 \text{ in. lbs}$$

ANSWERS TO PROBLEMS - RACK AND PINION

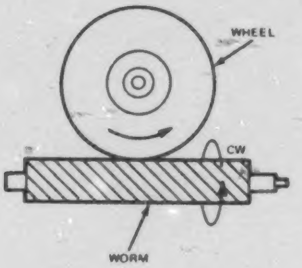
10. In problem 9, what force does the operator apply to the 8 in. feed wheel arms?

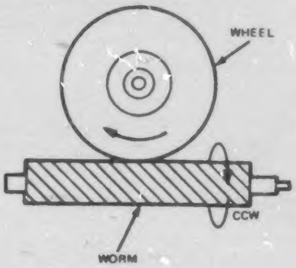
$$f_p = \frac{T_p}{r} = 3/8 = .375 \text{ lbs} = 6 \text{ oz.}$$

MECHANISMS
UNIT III

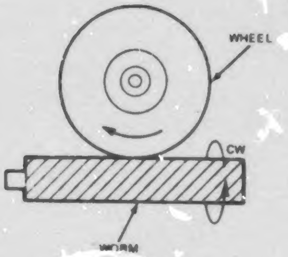
ANSWERS TO PROBLEMS - WORM AND WHEEL

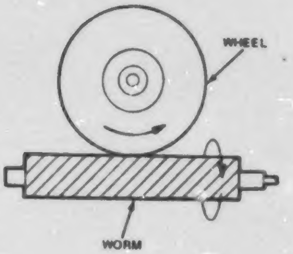
1. Worm screws may be either right- or lefthanded. Make a sketch showing the direction of wheel rotation if a right handed worm is turned clockwise and counterclockwise.


WHEEL
CW
WORM


WHEEL
CCW
WORM

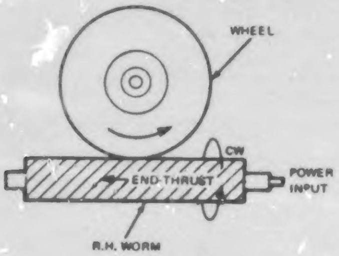
2. Repeat problem 1 using a left handed worm.

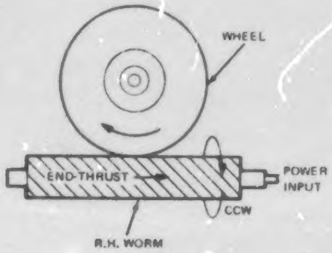

WHEEL
CW
WORM

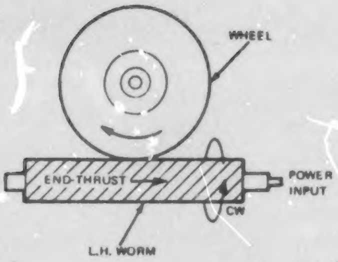


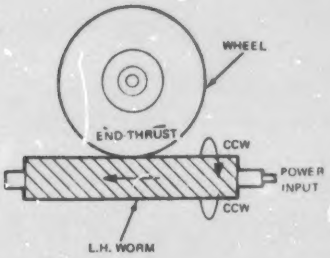
ANSWERS TO PROBLEMS - WORM AND WHEEL

3. Make a sketch showing the direction of end-thrust for the worms in problems 1 and 2.

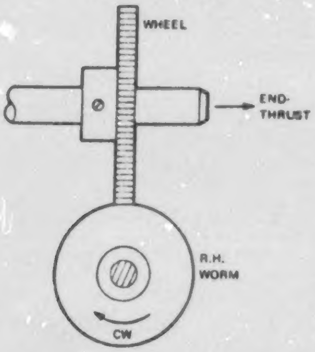

WHEEL
CW
END-THRUST
POWER INPUT
R.H. WORM

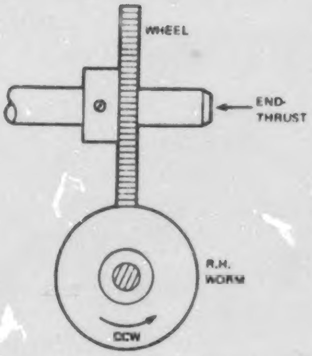

WHEEL
END-THRUST
POWER INPUT
CCW
R.H. WORM

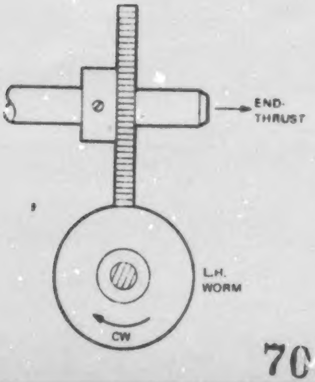

WHEEL
END-THRUST
POWER INPUT
CW
L.H. WORM

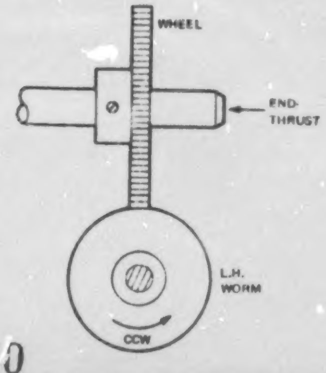

WHEEL
END-THRUST
CCW
POWER INPUT
CCW
L.H. WORM

4. Repeat problem 3 for worm wheel.


WHEEL
END-THRUST
R.H. WORM
CW


WHEEL
END-THRUST
R.H. WORM
CCW


END-THRUST
L.H. WORM
CW


WHEEL
END-THRUST
L.H. WORM
CCW

ANSWERS TO PROBLEMS - WORM AND WHEEL

5. A 100-tooth worm wheel is to be used in a speed reducer. What is the gear ratio if the worm has one of the following?

a. A single thread	c. A triple thread
b. A double thread	d. A quadruple thread

a. gear ratio $= \frac{N}{K} = \frac{100}{1} =$ 100:1

b. gear ratio $= \frac{N}{K} = \frac{100}{2} =$ 50:1

c. gear ratio $= \frac{N}{K} = \frac{100}{3} =$ 100:3

d. gear ratio $= \frac{N}{K} = \frac{100}{4} =$ 25:1

6. A double threaded worm drives a 120-tooth wheel, and the mechanism has an efficiency of 70 percent. If the output torque is 250 in.-oz. what is the input torque?

$$T_W = \frac{1}{\eta} T_g \frac{K}{N} = \frac{1}{7} X \; 250 \; X \frac{2}{120} = .31 \text{ ft-lbs}$$

7. The worm in problem 6 is turning 1750 RPM. What is the power output?

$$P = \frac{W}{t} = \frac{fs}{t} = \frac{T\theta \; g}{t} = T \; X \; \omega \; X \; 2\pi = \frac{\text{ft-lbs}}{} \; X \; \frac{\omega}{\text{min}} \; X \; \frac{2\pi \text{ rad}}{} \; X \; \eta$$

$$= .031 \; X \; 1750 \; X \; 2 \; X \; 3.14 \; X \; .7 = 238 \text{ ft-lbs/min}$$

NOTE: θ in radians

8. What is the input power in problem 7?

$$P_i = \frac{P_o}{\eta} = \frac{238}{.7} = 340 \text{ ft-lbs/min}$$

9. List at least three practical applications of a worm-and-wheel mechanisms.

The worm-and-wheel mechanism is used as an indexing device on some measuring instruments and machine tools, as a reduction gear for connecting a high speed motor to a much slower line shaft, or any other low speed, high torque transfer situation.

ANSWERS TO PROBLEMS - WORM AND WHEEL

10. How could a worm-and-wheel be made to operate between shafts that were 75° apart?

    Although worm-and-wheel mechanisms normally operate on shafts at right angles, slight deviations from 90° can be obtained by altering the helix angle on the wheel to mate with the worm at the adjusted shaft angle.

MECHANISMS

UNIT III

ANSWERS TO PROBLEMS - COMBINED MECHANISMS

1. If the angular velocity of the input gear in the experimental mechanism was 850 radians per second, what would be the velocity of the block?

$$\omega_4 = \omega_1 \cdot \frac{N_1 N_3}{N_2 N_4} = 850 \frac{50 \times 36}{72 \times 95} = 224 \text{ radians/second} = \omega_{worm}$$

$$\omega_g = \omega_w \times \frac{k}{N} = 224 \times \frac{2}{60} = 7.47 \text{ radians per second} = \omega_s$$

$$\omega_s = \frac{7.47}{2\pi} \text{ rev. per second} = 1.19 \text{ rev. per second}$$

$$v_b = P_s \omega_s = .050 \times 1.19 = .0601 \text{ in./sec.}$$

2. If the input gear in the experimental mechanism turns 1130 RPM, what would be the linear velocity of the block?

$$v_b = \frac{P_s \omega_1}{60} \times \frac{N_1 N_3 K}{N_2 N_4 N_g} = \frac{.0505 \times 1130 \times 50 \times 36 \times 2}{60 \times 72 \times 95 \times 60} = .00835 \text{ in./sec.}$$

3. How long would it take for the block in problem 1 to travel the length of the screw?

$$t = \frac{s}{v} = \frac{4.325 \text{ in.}}{.0601 \text{ in/sec}} = 72 \text{ sec.} = 1 \text{ min. } 12 \text{ sec.}$$

4. In problem 2 what was the velocity of the worm?

$$\omega_w = \omega_1 \frac{N_1 N_3}{N_2 N_4} = 1130 \times \frac{50 \times 36}{72 \times 95} = 298 \text{ RPM}$$

5. If the block in the experimental mechanism were driving a 300 ounce load, what would be the input torque? (NOTE: assume 100% efficiency throughout)

$$T_s = \frac{\text{[illegible]}\ s}{2 \pi \eta} = \frac{300 \times 1 \times .0505}{2 \times 3.14 \times 1} = 2.41 \text{ in. - oz.} = T_g$$

$$T_w = T_g \times \frac{k}{N} = 2.41 \times \frac{2}{60} = .08 \text{ in.-oz.} = T_4$$

ANSWERS TO PROBLEMS - COMBINED MECHANISMS

5 (conti.) -

$$T_1 = T_4 \frac{N_1 N_3}{N_2 N_4} = .08 \times \frac{50 \times 36}{72 \times 95} = .00021 \text{ in.-oz.}$$

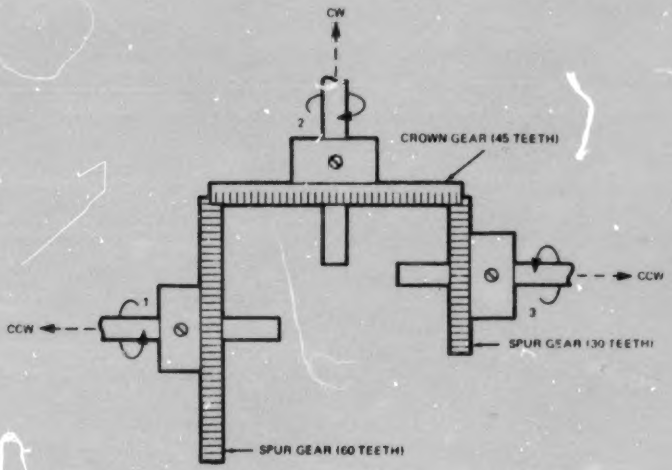
6. Using the velocity from problem 2 and the load from problem 5, determine the input horsepower.

$HP_i = \dfrac{T_i \times \omega_i \times 2\pi}{12 \times 16 \times 33000} = \dfrac{2.1 \times 10^{-4} \times 1130 \times 2 \times 3.1\text{[illegible]}}{12 \times 16 \times 3.3 \times 10^{-4}}$ [illegible] 35×10^{-8} HP

MECHANISMS
UNIT III

ANSWERS TO PROBLEMS - COUNTER ROTATORS

1. Discuss the operation of the mechanism shown below.



Assuming the crown gear is the input and is rotating clockwise, output gears 1 and 2 will rotate counterclockwise when viewed from their shaft end. Notice that gears 1 and 3 are actually rotating in opposite directions. The pitch circle velocities of all three gears are the same, but the angular velocities and displacement are inversely proportional to the tooth counts. Torque supplied by input 2 will be distributed to outputs 1 and 3 in accordance with the following expression:

$$\frac{T_2}{D_2} = \frac{T_1}{D_1} + \frac{T_3}{D_3}$$

If gears 1 or 3 are used as inputs, a similar relationship exists. For example,

$$\frac{T_3}{D_3} = \frac{T_1}{D_1} + \frac{T_2}{D_2}$$

2. If the crown gear in figure 18-6 runs clockwise (viewed from shaft end) at 1825 RPM, how fast will the two spur gears turn?

$$\omega_3 = -\omega_2 \frac{N_2}{N_3} = -1825 \times \frac{45}{30} = -2737.5 \text{ RPM}$$

$$\omega_1 = -\omega_2 \frac{N_2}{N_1} = -1825 \times \frac{45}{60} = -1370 \text{ RPM}$$

ANSWERS TO PROBLEMS - COUNTER ROTATORS

3. In problem 2, which way will each spur gear turn?

   Each spur gear turns counterclockwise when viewed from its shaft end.

4. The counter rotator in figure 18-2 has loads at output 1 and 2 of 210 in.-oz. and 145 in.-oz. respectively. The tooth counts are $N_1 = N_2 = 24$ teeth. $N_3 = 60$ teeth and the gears are 32 pitch. What is the torque delivered to gear 3?

$$D = \frac{N}{P_d}$$

$$T_3 = D_3\left(\frac{T_1}{D_1} = \frac{T_2}{D_2}\right)$$

$$T_3 = \frac{N_3}{P_d}\left(\frac{T_1}{N_1/P_d} + \frac{T_2}{N_2/P_d}\right) = \frac{60}{32}\left(\frac{210}{24/32} + \frac{1145}{24/32}\right) = 887.5 \text{ in.-oz.}$$

5. The counter rotator in figure 18-2 is used in such a way that shaft 2 is the input. The load on shaft 3 is 85 in.-oz. while shaft 1 is loaded with 104 in.-oz. What is the torque supplied to shaft 2? (Use the pitch and tooth counts from problem 4.)

$$T_2 = D_2\left(\frac{T_3}{D_3} + \frac{T_1}{D_1}\right)$$

$$T_2 = \frac{N_2}{P_d}\left(\frac{T_3}{N_3/P_d} + \frac{T_1}{N_1/P_d}\right) = \frac{24}{32}\left(\frac{85}{60/32} + \frac{104}{24/32}\right) = 138 \text{ in.-oz.}$$

6. If shaft 1 in problem 5 turns at 3600 RPM, what is the horsepower supplied by the source?

$$HP = \frac{2T\pi\ \omega}{12 \times 16 \times 33{,}000} = \frac{2 \times 138 \times 3.14 \times 3600}{12 \times 16 \times 33{,}000} = 0.492$$

7. Repeat problem 6 for a shaft 3 velocity of 3600 RPM.

$$\omega_2 = \omega_3 \frac{N_3}{N_2}$$

$$HP = \frac{2T\pi\ \omega\ 2}{12 \times 16 \times 33{,}000} = \frac{2 \times 138 \times 3.14 \times 3600}{12 \times 16 \times 33{,}000}\left(\frac{60}{24}\right) = 1.23$$

MECHANISMS

UNIT III

ANSWERS TO PROBLEMS - MECHANICAL DIFFERENTIALS

1. List several practical applications for mechanical differentials.

   a. for adding and subtracting shaft movements in servo systems;
   b. for addition, subtraction, multiplication, and division in computing machines;
   c. to measure torque in rotating shafts;
   d. as brakes or clutches to control the operation of other equipment;
   e. to introduce data to computers;
   f. in automotive rear ends.

2. A certain differential has an input 1 of 1750 RPM and an input 2 in the same direction of 1720 RPM. What is the spider shaft velocity and which way does it turn?

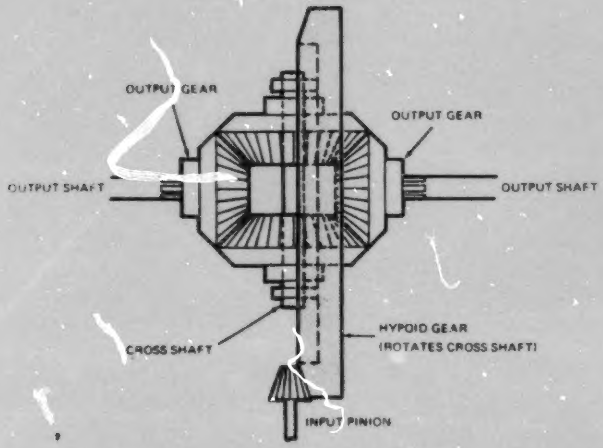
$$\omega_s = 1/2(\omega_1 + \omega_2) = 1/2\ (1750 + 1720)$$

3. What would be the results in problem 2 if the inputs turned in opposite directions?

$$\omega_s = 1/2\ (\omega_1 - \omega_2) = 1/2\ (1750 - 1720)$$

$= 15$ RPM. This rotation will be in the same direction as ω_1.

4. Make a sketch showing how a differential can be used to give two outputs from a single input. The outputs should be in line with each other and at right angles to the input.



ANSWERS TO PROBLEMS - MECHANICAL DIFFERENTIALS

5. Where might you find a differential of the type described in problem 4?

Automotive rear end differential.

6. A certain differential has input torques of 130 ft.-lb. and 90 ft.-lb. What is the spider shaft torque?

If the input torques are in the same direction:

$$T_s = T_1 + T_2 = 130 + 90 = 220 \text{ ft.-lbs.}$$

If the input torques are in opposite directions:

$$T_s = T_1 - T_2 = 130 - 90 = 40 \text{ ft.-lbs.}$$

7. A differential is set up with the spider shaft fixed. A velocity of 3000 RPM is applied to input 1. A mechanical load of 175 in.-oz. is connected to the remaining shaft. What is the torque on the spider shaft?

$$T_s = 175 \text{ in.-oz.}$$

NOTE: In this case T_1, T_2 and T_s are all equal.

8. What is the angular velocity of the load in problem 7?

$$\omega_1 = 2\omega_s - \omega_2 = 2 \times 0 - 3{,}000 = -3{,}000 \text{ RPM}$$

NOTE: Negative sign denotes rotation in opposite directions unless the mechanism is viewed from junction block.

9. What horsepower is being delivered to the load in problem 7?

$$HP = \frac{2\pi T\omega}{12 \times 16 \times 33{,}000} = \frac{2 \times 3.14 \times 175 \times 3{,}000}{12 \times 16 \times 33{,}000} = .516 \; HP_\ell$$

10. What horsepower is being delivered by the source in problem 7?

$$HP_\ell = HP_1 = .516$$

ANSWERS TO PROBLEMS - MECHANICAL DIFFERENTIALS

11. What horsepower is being delivered to the spider shaft in problem 7?

    hp = 0

    NOTE: Since the spider shaft is locked it cannot move and no work is accomplished.

12. What practical application can you think of for the arrangement described in problem 7?

    This arrangement allows for the measurement of transmitted torque on the spider shaft.

MECHANISMS

UNIT III

TEST ANSWERS

1. a. 2
   b. 13
   c. 10
   d. 14
   e. 8
   f. 4
   g. 1
   h. 6
   i. 3
   j. 11
   k. 7
   l. 5
   m. 9
   n. 12

2. A. $S_r = 6.2832$ in.

   B. $T_p = 90$ in.-lbs.

   $fr = 120$ lbs.

3. $T_w = 7.2727$ in.-oz.

4. The worm-and-wheel mechanism is used as an indexing device on some measuring instruments and machine tools, as a reduction gear for connecting a high speed motor to a much slower line shaft, or any other low speed, high torque transfer situation.

5. $T_s = \dfrac{200 \times 1 \times 0.0505}{2 \times 3.14 \times 1} = 1.608$ in.-oz.

6. Assuming the crown gear is the input and is rotating clockwise, output gears 1 and 2 will rotate counterclockwise when viewed from their shaft end. Notice that gears 1 and 3 are actually rotating in opposite directions. The pitch circle velocities of all three gears are the same, but the angular velocities and displacement are inversely proportional to the tooth counts. Torque supplied by input 2 will be distributed to outputs 1 and 3 in accordance with the following expression:

$$\frac{T_2}{D_2} = \frac{T_1}{D_1} + \frac{T_3}{D_3}$$

If gears 1 or 3 are used as inputs, a similar relationship exists. For example,

$$\frac{T_3}{D_3} = \frac{T_1}{D_1}, + \frac{T_2}{D_2}$$

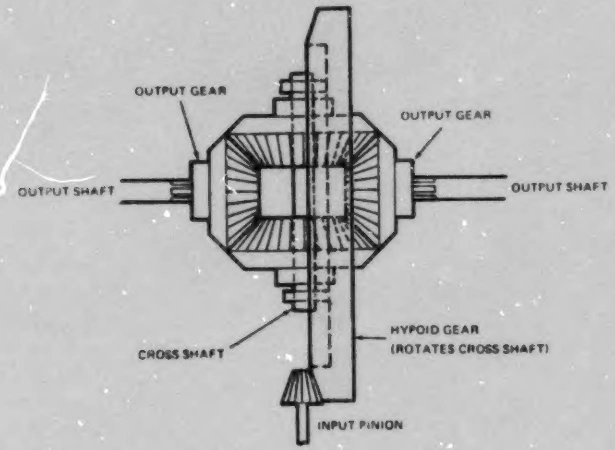
TEST ANSWERS

6 (conti.).

Notice, in this case, gear 2 must carry the torque needed on output shaft 2 and transmit torque to gear 1. This increases the demand on the meshing teeth of gears 2 and 3 since all the force needed to produce the output torques must be transmitted through this point.

7. a. for adding and subtracting shaft movements in servo systems;
   b. for addition, subtraction, multiplication, and division in computing machines;
   c. to measure torque in rotating shafts;
   d. as brakes or clutches to control the operation of other equipment;
   e. to introduce data to computers;
   f. in automotive rear ends.

8.


OUTPUT GEAR
OUTPUT GEAR
OUTPUT SHAFT
OUTPUT SHAFT
CROSS SHAFT
HYPOID GEAR
(ROTATES CROSS SHAFT)
INPUT PINION

MECHANICAL DEVICES

UNIT IV

DRIVES

DRIVES

UNIT IV

OBJECTIVES

After completing this unit, the student should be able to select between a belt, toothed, chain, disk, or rotary cam drives depending on the application. This knowledge will be shown by completing an assignment sheet, lab procedures, chapter problems and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with drives to their correct definitions.
2. Calculate basic belt drive values.
3. Name advantages of toothed belt drive over belt drive.
4. Name applications of drive chains.
5. Calculate values for disk drive.
6. Show relationships between various values of disk drives.
7. Calculate various values of rotary cams.
8. Discuss the effect speed and tension have on float and bounce of a rotary cam.
9. Demonstrate the ability to
    a. Experimentally investigate belt drive characteristics
    b. Experimentally observe operating characteristics of toothed belts.
    c. Observe basic principles of belt drives.
    d. Observe operating principles of frictional disk drives.
    e. Observe operating characteristics of the single lobe rotary cam.

DRIVES

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with procedure sheet and Drives text.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss labs and problems from Drives.

   F. Demonstrate advantages of toothed belt and belt drives.

   G. Demonstrate disk drive and rotary cam drives mechanics.

   H. Assist students in investigating belt drives.

   I. Assist students in constructing cam mechanism.

   J. Assist students in lab calculations.

   K. Give test.

II. Student

   A. Read objective sheet.

   B. Complete procedure sheets.

   C. Take test.

DRIVES

UNIT IV

INSTRUCTIONAL MATERIAL

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheet.

   C. Test.

   D. Answers to assignment sheets.

   E. Answers to test.

II. References

   A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

   B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

   C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

   A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development,1981.

DRIVES

UNIT IV

PROCEDURE SHEET

_____1. Complete Assignment Sheet #1 - Terms associated with "Drives".

_____2. Study Belt Drives, "Drives", Pages 149-152.

_____3. Do Lab Procedure, Pages 153-155.

_____4. Stop Have your instructor review your results. If necessary redo Step 3.

_____5. Complete Problems, "Drives", Page 155.

_____6. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 7. Otherwise repeat Steps 2, 5 and 6.

_____7. Write An informal lab report for Belt Drives. Use the informal format described on Page 207, "Drives".

_____8. Study Toothed Belts, "Drives", Pages 175-178.

_____9. Do Lab Procedure, Pages 179-181.

____10. Stop Have your instructor review your results. If necessary redo Step 9.

____11. Complete Problems, "Drives", Page 181.

____12. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 13. Otherwise repeat Steps 8, 11 and 12.

____13. Write An informal lab report for Toothed Belts. Use the informal format described on Page 207, "Drives".

____14. Study Chain Drives, "Drives", Pages 168-172.

____15. Do Lab Procedures, "Drives", Pages 173-174.

____16. Stop Have your instructor review your results. If necessary redo Step 15.

____17. Complete Problems, "Drives", Page 174.

PROCEDURE SHEET

____18.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 19. Otherwise repeat Steps 14, 17 and 18.
____19.	Write	An informal lab report for Chain Drives. Use the informal format described on Page 207, "Drives".
____20.	Study	Disk Drives, "Drives", Pages 182-184.
____21.	Do	Lab Procedures, "Drives", Pages 185-187.
____22.	Stop	Have your instructor review your results. If necessary redo Step 21.
____23.	Complete	Problems, "Drives", Page 188.
____24.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 25. Otherwise repeat Steps 20, 23 and 24.
____25.	Write	An informal lab report for Disk Drives. Use the informal format described on Page 207, "Drives".
____26.	Study	Rotary Cams, "Drives", Pages 189-192.
____27.	Do	Lab Procedures, "Drives", Pages 192-194.
____28.	Stop	Have your instructor review your results. If necessary redo Step 27.
____29.	Complete	Problems, "Drives", Page 194.
____30.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 31. Otherwise repeat Steps 26, 29 and 30.
____31.	Write	An informal lab report for Rotary Cams. Use the informal format described on Page 207, "Drives".
____32.	Turn-In	All lab reports before continuing.
____33.	Review	Chapters 22, 25, 26, 27 and 28, "Drives".

PROCEDURE SHEET

____34. Complete Unit Test - Drives

____35. Stop Have your instructor evaluate the Unit Test - Drives. If your instructor is satisfied with your performance, continue on to Unit V. Otherwise review the areas suggested by your instructor and repeat Steps 34 and 35.

DRIVES

UNIT IV

ASSIGNMENT SHEET #1 - TERMS AND DEFINITIONS ASSOCIATED WITH DRIVES.

Using Pages 149 - 194, of "Drives", write a definition for each of the following terms:

1. Belts -
2. Pulleys -
3. Belt Configuration -
4. Chains -
5. Sprocket -
6. Toothed Belt -
7. Positively Coupled Drive -
8. Disk or Friction Drives -

DRIVES

UNIT IV

TEST

NAME____SCORE____________

1. Match the terms associated with drives to their correct definitions. Place the correct number in the blank.

_____a. Flexible connectors (similar to belts) which provide a positive drive.

_____b. A positive drive belt with transverse protruding teeth.

_____c. Any gear form in which the pitch surfaces roll on one another to transmit power by friction.

_____d. Refers to the path the belt takes when driving the pulleys.

_____e. A drive in which the geometry of the system eliminates slippage.

_____f. Flexible connectors commonly used for transmitting power between shafts whose center distance is too great for gearing.

_____g. The wheel over which chains run.

_____h. Although pulleys may serve other functions such as pulley blocks and hoists, they are referred to in this unit as wheels which are connected by belts.

1. Sprocket
2. Disk or Friction Drives
3. Belt Configuration
4. Pulleys
5. Chains
6. Positively Coupled Drive
7. Toothed Belt
8. Belts

2. Show your work for the following belt problems:

A. Pulleys having diameters of 2.5 in. and 4 in. are mounted with their centers 8 in. apart. The smaller pulley is rotating at 1700 RPM. How fast is the larger pulley rotating?

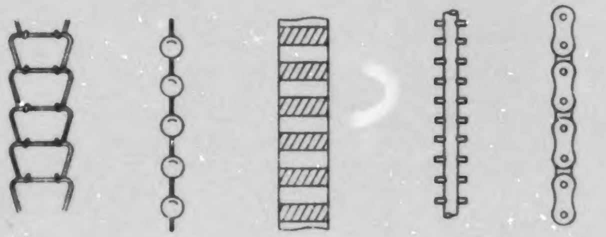
TEST

B. What would be the result in problem 2A if the larger pulley is the follower and there is 5% slippage?

C. Name an advantage of a toothed belt drive over a belt drive.

3. Which of the chains in Figure 1 can be crossed to make the sprockets turn in opposite directions?

FIGURE 1



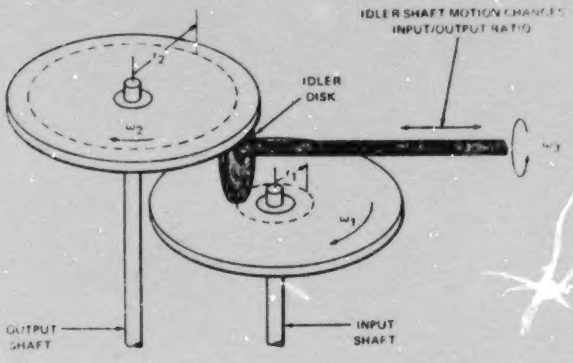
(A) LADDER CHAIN (B) BEAD CHAIN (C) COG BELT (D) TOOTHED BELT (E) ROLLER CHAIN

TEST

4. Show your work for the following disk drive problems.

   A. A disk drive of the type shown in Figure 2 has input and output disks that are 6 in. OD. The centers of the input and output disks are 3.5 in. apart and the idler disk is 1 in. OD. What is the range of the output velocity if the input velocity is 500 RPM? (minimum r_1 = 0.5 in. and r_2=3 in.)

FIGURE 2


IDLER SHAFT MOTION CHANGES INPUT/OUTPUT RATIO
r_2
IDLER DISK
ω_2
ω_3
r_1
ω_1
OUTPUT SHAFT
INPUT SHAFT

   B. Make a sketch of the relationship between idler positions (horizontal axis) and output velocity (vertical axis) for the mechanism in problem 4A.

TEST

5. Show your work for the following rotary cam problem.

   A. A single cam is to be used with a 1.0 RPM timing motor to switch on an electric sign. The sign is to be on for 12 sec, off for 21 sec, then on for 16 sec, and off for 11 sec each minute. Sketch a cam that would perform this job. Show the dwell times and angles.

   B. Discuss how follower float and bounce affect the on and off dwell times of a cam application.

6. End oftest. STOP! Have your instructor evaluate your test. If you received a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

MATHEMATICAL EXPRESSIONS

$$\ell = r\theta_s = \frac{d}{2}\theta_s$$

$$\ell = R\theta_L = \frac{D}{2}\theta_L$$

$$\frac{d}{2}\theta_s = \frac{D}{2}\theta_L$$

$$\frac{d}{D} = \frac{\theta_L}{\theta_s}$$

$$d = D_o \frac{N}{N+2}$$

$$\frac{d}{D} = \frac{\theta_L/t}{\theta_s/t}$$

$$\frac{d}{D} = \frac{\omega_L}{\omega_s}$$

$$f = \frac{T_L}{R} = 2\frac{T_L}{D}$$

$$T_s = f_r = f\frac{d}{2}$$

$$S = R - r \text{ in.}$$

$$\theta + \beta = 2\pi \text{ rad}$$

$$T = \frac{1}{\omega_c} \text{ min/rev.}$$

$$t_{on} = \frac{\theta}{2\pi}T = \frac{\theta}{2\pi\omega_c} \text{ min.}$$

$$t_{off} = \frac{\beta}{2\pi}T = \frac{\beta}{2\pi\omega_c} \text{ min.}$$

$$-\frac{\omega_s}{\omega_L} = \frac{R}{r} = \frac{D}{d} = -\frac{\theta_s}{\theta_L} = -\frac{T_L}{T_s}$$

$$\frac{r_1}{r_2} = \frac{d_1}{d_2} = -\frac{\omega_2}{\omega_1} = -\frac{\theta_2}{\theta_1} = -\frac{T_1}{T_2}$$

$$\frac{r_1}{r_2} = \frac{d_1}{d_2} = \frac{\omega_2}{\omega_1} = \frac{\theta_2}{\theta_1} = \frac{T_1}{T_2}$$

$$\frac{d}{D} = \frac{T_s}{T_L}$$

$$\frac{d}{D} = \frac{\theta_L}{\theta_s} = \frac{\omega_L}{\omega_s} = \frac{T_s}{T_L}$$

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(D\theta_1 - d\theta_2)$$

$$\theta_1 = \pi + 2 \text{ arc sin } \frac{D-d}{2C}$$

$$\frac{d}{D} = -\frac{\theta_L}{\theta_s} = -\frac{\omega_L}{\omega_s} = -\frac{T_s}{T_L}$$

$$L = \sqrt{4C^2 - (D+d)^2} + (1/2)\theta_1(D+d)$$

$$\theta_2 = \pi - 2 \text{ arc sin } \frac{D+d}{2C}$$

$$\theta = \pi + 2 \text{ arc sin } \frac{D+d}{2C}$$

$$f = 2\frac{T_s}{d}$$

$$2\frac{T_L}{D} = 2\frac{T_s}{d}$$

$$t_{on} = \frac{\theta}{360\omega_c} \text{ min.}$$

$$t_{off} = \frac{\beta}{360\omega_c} \text{ min.}$$

$$t_{on} = 60\frac{\theta}{360\omega_c} = \frac{\theta}{6\omega_c} \text{ sec.}$$

$$t_{off} = 60\frac{\beta}{360\omega_c} = \frac{\beta}{6\omega_c} \text{ sec.}$$

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MATHEMATICAL EXPRESSIONS

$$V_b = \omega R$$

$$V_b = \omega_L R = \frac{1}{2}\omega_L D$$

$$V_b = \omega_s r = \frac{1}{2}\omega_s d$$

$$\frac{1}{2}\omega_L D = \frac{1}{2}\omega_s d$$

$$\frac{\omega_L}{\omega_s} = \frac{d}{D}$$

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(D\theta_L + d\theta_s)$$

$$\theta_L = \pi + 2 \text{ arc sin } \frac{D-d}{2C}$$

$$\theta_s = \pi - 2 \text{ arc sin } \frac{D-d}{2C}$$

$$\frac{\omega_L}{\omega_s} = -\frac{d}{D}$$

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}\theta(D+d)$$

$$\theta = \pi + 2 \text{ arc sin } \frac{D+d}{2C}$$

$$\sin\frac{\gamma}{2} = \frac{P/2}{D/2} = \frac{P}{D}$$

$$\gamma = \frac{360^\circ}{N}$$

$$\frac{\gamma}{2} = \frac{1}{2}\left(\frac{360^\circ}{N}\right) = \frac{180^\circ}{N}$$

$$\sin\frac{180^\circ}{N} = \frac{P}{D}$$

$$D = \frac{P}{\sin\frac{180^\circ}{N}}$$

$$s = r\theta_s = \frac{d}{2}\theta_s$$

$$s = R\theta_L = \frac{D}{2}\theta_L$$

$$\frac{d}{2}\theta_s = \frac{D}{2}\theta_L$$

$$d\theta_s = D\theta_L$$

$$\frac{d}{D} = \frac{\theta_L}{\theta_s}$$

$$\frac{n}{N} = \frac{\theta_L}{\theta_s}$$

$$f_L = \frac{T_L}{D/2}$$

$$f_s = \frac{T_s}{d/2}$$

$$\theta_L = \theta_s\frac{n}{N}$$

$$\frac{n}{N} = \frac{\theta_L}{\theta_s}$$

$$f_L = \frac{T_L}{D/2}$$

$$f_s = \frac{T_s}{d/2}$$

$$f_L = f_s$$

$$\frac{T_L}{D/2} = \frac{T_s}{d/2}$$

$$\frac{d}{D} = \frac{T_s}{T_L}$$

$$d\frac{\theta_s}{t} = D\frac{\theta_L}{t}$$

$$d\,\omega_s = D\,\omega_L$$

$$\frac{d}{D} = \frac{\omega_L}{\omega_s}$$

$$\theta_L = \theta_s\frac{n}{N}$$

$$\frac{d}{D} = \frac{n}{N} = \frac{\theta_L}{\theta_s} = \frac{\omega_L}{\omega_s} = \frac{T_s}{T_L}$$

$$\frac{L}{P} = \frac{2C}{P} + \frac{n+N}{2} + \frac{P}{C}\left(\frac{N-n}{2\pi}\right)^2$$

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DRIVES

UNIT IV

ANSWERS TO ASSIGNMENT SHEET #1

1. Belts - Flexible connectors commonly used for transmitting power between shafts whose center distance is too great for gearing. (Belts also lend themselves to other uses not discussed in this experiment, such as conveyors, hoists, and variable-speed drives.) Belts are made from a variety of materials including leather, fabric, rubber and endless combinations of other natural and synthetic materials. Some belts (such as round, Vee and flat belts) rely on friction to transmit power. However, when slippage must be eliminated, belts may take on the forms of timing or cog belts and toothed belts.

2. Pulleys - Although pulleys may serve other functions such as pulley blocks and hoists, they are referred to in this unit as wheels which are connected by belts. The shape of the pulley must be compatible with the belt to provide driving friction and minimize wear. Flat belt pulleys may be flanged or crowned. The crown pulley allows "tracking" of the belt in much the same way as the tracking wheel of a brand saw.

3. Belt Configuration - Refers to the path the belt takes when driving the pulleys. Some of the most common configurations are the open belt, serpentine (a type of open belt involving more than two pulleys) and the crossed belt. The open belt arrangement allows the shafts to turn in the same direction, whereas the crossed belt provides for opposite directions of rotation. Due to the obvious disadvantages of the belt rubbing on itself, crossed belts should be avoided whenever possible. Although many configurations are possible, care must be taken to see that as the belt approaches the pulley, the centerline of the belt lies in a plane perpendicular to the axis of the pulley. However, the belt may leave the pulley at some angle other than 90°.

4. Chains - Flexible connectors (similar to belts) which provide a positive drive. Chains are made up of links which may take several forms. The ladder chain, for example, is made of multiple links of wire. Although it is rather inexpensive, it is complicated to connect and not suitable for precision applications. The bead chain is a light-load, slow-speed chain made up of multiple stamp balls. The chain itself is inexpensive but the necessary dimpled pulleys are rather costly. The roller chain is probably the most common chain. It is made up of two main types of links, a roller link and a connecting link. Roller chains commonly contain a master link allowing links to be added or removed. A cog or timing belt is actually a positive drive belt. The lugs may be metal or molded rubber. The toothed belt is another type of positive drive belt similar in construction to a round belt, but with transverse protruding teeth.

ANSWERS TO ASSIGNMENT SHEET #1

5. Sprocket - The wheel over which chains run. Sprocket teeth are standardized and designed to accommodate the links in the chain.

6. Toothed Belt - A positive drive belt with transverse protruding teeth. The toothed belt runs in a grooved gear pulley with lateral projections to mesh with each tooth.

7. Positively Coupled Drive - A drive in which the geometry of the system eliminates slippage. Toothed gears, worms, screws and chains are examples of this type of drive.

8. Disk or Friction Drives - Any gear form in which the pitch surfaces roll on one another to transmit power by friction. Variable drives may use a disk and a rubber-tired wheel.

DRIVES

UNIT IV

ANSWERS TO PROBLEMS - BELT DRIVES

1. Pulleys have diameters of 2 in. and 3.5 in. are mounted with their centers 8 in. apart. The smaller pulley is rotating at 1725 RPM. How fast is the larger pulley rotating? (ignore slippage)

$$\omega_L = \omega_s \frac{d}{D} = 1725 \times \frac{2}{3.5} = 986 \text{ RPM}$$

2. What would be the result in problem 1 if the larger pulley is the follower and there is 5% slippage?

$$\text{actual } \omega_L = (1.00 - .05)\ \omega_L = .95 \times 986 = 937 \text{ RPM}$$

3. What would be the result in problem 1 if the smaller pulley is the follower and there is 5% slippage ?

$$\text{actual } \omega_L = (1.00 - .05)\ \omega_s \frac{d}{d} = .95 \times 1725 \times \frac{2}{3.5} = 936 \text{ RPM}$$

4. What is the length of the belt in problem 1 if the pulleys are being used in the open belt configuration?

$$L = \sqrt{4C^2 - (D - d)^2} + \frac{1}{2}\left[D\left(\pi + 2 \text{ arc sin } \frac{D-d}{2C}\right) + d\left(\pi - 2 \text{ arc sin } \frac{D-d}{2C}\right)\right]$$

$$L = \sqrt{4.8^2 - (3.5 - 2)^2} + \frac{1}{2}\left[3.5\left(3.14 + 2 \text{ arc sin } \frac{3.5 - 2}{2 \times 8}\right)\right.$$

$$\left. + 2\left(3.14 - 2 \text{ arc sin } \frac{3.5 - 2}{2 \times 8}\right)\right] = 24.6 \text{ in.}$$

5. What is the length of the belt in problem 1 if the pulleys are being used in a crossed belt configuration ?

$$L = \sqrt{4C^2 - (D - d)^2} + \frac{1}{2}\left(\pi + 2 \text{ arc sin } \frac{D + d}{2C}\right)(D + d)$$

$$L = 4 \times 8^2 - (3.5 - 2)^2 + \frac{1}{2}\left(3.14 + 2 \text{ arc sin } \frac{3.5 + 2}{2 \times 8}\right)(3.5 + 2) = 25.4 \text{ in}$$

ANSWERS TO PROBLEMS - BELT DRIVES

6. What are the contact angles in problem 4?

$$\theta_L = \pi + 2 \text{ arc sin } \frac{D - d}{2C} = 180^o + 2 \text{ arc sin } \frac{3.5 - 2}{2X8} = 190.8^o$$

$$\theta_L = \pi - 2 \text{ arc sin } \frac{3.5 - 2}{2X8} = 169.2^o$$

7. What is the contact angle in problem 5?

$$\theta = \pi + 2 \text{ arc sin } \frac{D+d}{2C} = 180^o + 2 \text{ arc sin } \frac{3.5 + 2}{2X8} = 220.2^o$$

OR $\theta = 3.14 + 2 \text{ arc sin } \frac{3.5 + 2}{2X8}$ or $\theta = 3.84$ radians

DRIVES

UNIT IV

ANSWERS TO PROBLEMS - TOOTHED BELTS

1. What was the diametrical pitch of the pulleys you used in this experiment?

$$P_d = \frac{N}{D}$$

$$P_{d_1} = \frac{30}{.928} = 32.2$$

$$P_{d_2} = \frac{56}{1.738} = 32.1$$

$$P_d = 32$$

$$P_{d_3} = \frac{48}{1.49} = 32.1$$

2. What is the circular pitch of the pulleys used in this experiment?

$$P_c = \frac{\pi}{P_d} = \frac{3.14}{32} = .0982$$

3. What was the pitch of the belt used in the experiment?

belt pitch = P_c = .0982

4. Compute the tooth ratios n/N, n/N_1, and N_1/N for the pulleys used in the experiment.

$n/N = 30/56 = .535$ $\quad n/N_1 = 30/48 = .625$ $\quad N_1/N = 48/56 = .858$

5. How do the tooth ratios computed in problem 4 compare to the diameter ratios computed in step 14 of the procedure?

		difference of ratios:
$\frac{d}{D} = .534$	$\frac{n}{N} = .535$	.001
$\frac{d}{D_1} = .622$	$\frac{n}{N_1} = .625$	.003
$\frac{D_1}{D} = .859$	$\frac{N_1}{N} = .858$	.001

ANSWERS TO PROBLEMS - TOOTHED BELTS

6. Show algebraically that n/N = d/D for a toothed pulley.

$$P_d = \frac{N}{D} \qquad P_{d_1} = P_{d_2} \qquad \frac{n}{d} = \frac{N}{D} \qquad \frac{n}{N} = \frac{d}{D}$$

7. Two toothed pulleys are 32 pitch and have OD's of 0.500 in. and 1.000 in. with a center distance of 3.75. What is the minimum length belt that should be used for the crossed belt configuration?

$$D = \frac{D_o P_d - 2}{P_d} \qquad \frac{1 \text{ X } 32 - 2}{32} = 0.94 \text{ in.}$$

$$d = \frac{d_o P_d - 2}{P_d} = \frac{.5 \text{ X } 32 - 2}{32} = 0.44 \text{ in.}$$

$$\theta = \pi + 2 \text{ arc sin } \frac{D + d}{2C} = 3.14 + 2 \text{ arc sin } \frac{.94 + .44}{2 \text{ X } 3.75} = 3.51 \text{ radians}$$

$$L = \sqrt{4C^2 - (D - d)^2} + 1/2\theta \; (D + d)$$

$$L = \sqrt{4 \times (3.75)^2 - (.94 - .44)^2} + 1/2\,(3.51)\,(.94 + .44) = 9.83 \text{ inches}$$

8. What is the velocity ratio in problem 7?

$$\frac{d}{D} = \frac{\dfrac{d_o P_d - 2}{P_d}}{\dfrac{D_o P_d - 2}{P_d}} = -\frac{\omega_L}{\omega_s}$$

$$\frac{\omega_L}{\omega_s} = -\frac{\dfrac{.5 \text{ X } 32 - 2}{32}}{\dfrac{1 \text{ X } 32 - 2}{32}} = -.466$$

DRIVES

UNIT IV

ANSWERS TO PROBLEMS - CHAIN DRIVES

1. Use an American Standard roller chain table to find the pitch of American Standard chains number 25, 40, 80, and 120.

ASA number	pitch
25	5/16 in.
40	1/2 in.
80	1 in.
120	1-1/2 in.

2. A 21-tooth sprocket is used to drive a 38-tooth sprocket with minature pitch (0.1475 in.) chain. If the large sprocket is turning 940 RPM, how fast is the small sprocket turning?

$$\omega_s = \omega_L \frac{N}{n} = 940 \times \frac{38}{21} = 1700 \text{ RPM}$$

3. What is the pitch diameter of each of the sprockets in problem 2?

$$D = \frac{P}{\sin \frac{180^\circ}{N}} = \frac{0.1475}{\sin \frac{180^\circ}{38}} = 1.8 \text{ inches}$$

$$d = \frac{P}{\sin \frac{180^\circ}{n}} = \frac{0.1475}{\sin \frac{180^\circ}{21}} = 0.984 \text{ inches}$$

4. The center distance in problem 2 is 2.45 in. What is the approximate chain length?

$$L = P \left[\frac{2C}{P} + \frac{n + N}{2} + \frac{P}{C} \left(\frac{N - n}{2\pi} \right)^2 \right]$$

$$L = 0.1475 \left[\frac{2 \times 2.45}{0.1475} + \frac{21 + 38}{2} + \frac{0.1475}{2.45} \left(\frac{38 - 21}{2 \times 3.14} \right)^2 \right] = 9.32 \text{ inches}$$

5. If the chain output torque in problem 2 is 165 in.-oz., what is the input torque? (ignor chain losses).

$$T_s = T_w \frac{n}{N} = 165 \times \frac{21}{38} = 91.5 \text{ in.-oz.}$$

ANSWERS TO PROBLEMS - CHAIN DRIVES

6. What is the input power in problem 2? (Give your answer in horsepower.)

$$HP = \frac{2\pi\ T_i\ \ \omega_i}{12 \times 16 \times 33{,}000} = \frac{2 \times 3.14 \times 91.5 \times 1700}{12 \times 16 \times 33{,}000} = 1.54$$

7. Which of the chains in figure 25-1 can be crossed to make the sprockets turn in opposite directions?

   The toothed belt lends itself well to this type application. However, the bead chain may also be used in this configuration for very light loads and slow speeds.

DRIVES

UNIT IV

ANSWERS TO PROBLEMS - DISK DRIVES

1. The phonograph mechanism in figure 27-1 has a 13 in. ID turntable. The motor shaft is 1/4 in ID and the largest drive wheel is 1-1/2 in. OD. The motor turns at 1725 RPM. At what speed will the turntable turn? (Ignore slippage)

$$\omega_T = \omega \frac{d_s}{D_t} = 1725 \times \frac{.25}{13} = 33\text{-}1/3 \text{ RPM}$$

2. What would be the results in problem one if there is 5% slippage in each disk contact?

$$\omega_T = .95 \times .95\ (.95\omega_s) \frac{d_s}{D_T} = .95 \times .95\ (.95 \times 1725) \frac{.25}{13} = 28.6 \text{ RPM}$$

3. What should be the diameter of the middle size drive wheel if the turntable speed is to be 45 RPM? (Notice that the idler drives the middle disk but the larger disk still drives the turntable.)

$$\omega_{\ell d} = \omega_T \frac{D_T}{D_{\ell d}} = 45 \times \frac{13}{1.5} = 390 \text{ RPM}$$

$$\omega_{\ell d} = \omega_{md} = 390 \text{ RPM}$$

$$D_{md} = D_s \frac{\omega_s}{\omega_{md}} = .25 \times \frac{1725}{390} = 1.11 \text{ in.}$$

4. Find the size of the small drive wheel if the turntable speed is to be 78 RPM.

$$\omega_{\ell d} = \omega_T \frac{D_T}{D_{\ell d}} = 78 \times \frac{13}{1.5} = 675 \text{ RPM}$$

$$\omega_{\ell d} = \omega_{sd} = 675 \text{ RPM}$$

$$D_{sd} = D_s \frac{\omega_s}{\omega_{sd}} = .25 \times \frac{1725}{675} = 0.64 \text{ in.}$$

ANSWERS TO PROBLEMS - DISK DRIVES

5. A disk drive of the type shown in figure 27-4 has input and output disks that are 6 in. OD. The centers of the input and output disks are 3.5 in. apart and the idler disk is 1 in. OD. What is the range of the output velocity if the input velocity is 500 RPM? (minimum $r_1 = 0.5$ in. and $r_2 = 3$ in.)

$$\omega_2 = \omega_1 \frac{1}{2} = 500 \times \frac{.5}{3} = 83\text{-}1/3 \text{ RPM}$$

($r_1 = 3$ in. and $r_2 = .5$ in.)

$$\omega_2 = \omega_1 \frac{r_1}{r_2} = 500 \times \frac{3}{.5} = 3000 \text{ RPM}$$

∴ Range of ω_2 is 83-1/3 RPM to 3000 RPM

6. Make a sketch of the relationship between idler positions (horizontal axis) and output velocity (verticle axis) for the mechanism in problem five.

DRIVES
UNIT IV

ANSWERS TO PROBLEMS - ROTARY CAMS

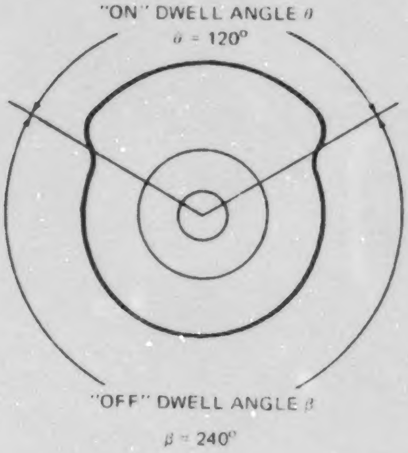
1. A cam of the type shown in figure 28-1 is rotating at 4 RPM. This cam operates a blinking light sign which is on 1/3 of the time. Assuming that the sign is on when the follower is on the cam, what are the dwell angles in degrees? Radians?

   NOTE: Let $t_{on} = 5$ sec. or $\frac{1}{3}$ of $\frac{1}{4}$ min.

   $$\theta = 6\omega_c t_{on} = 6 \times 4 \times 5 = 120^0 = \frac{2\pi}{3} \text{ radians}$$

   $$\beta = 2\pi - \theta = 360 - 120^0 = 240^0 = \frac{4\pi}{3} \text{ radians}$$

2. Make a sketch of the cam in problem 1.



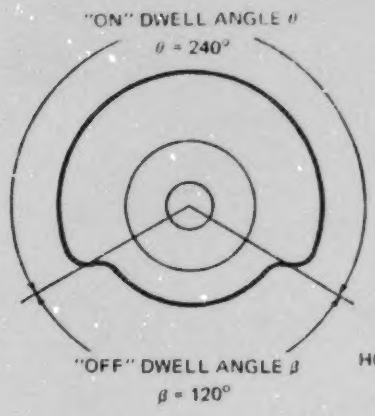
3. Assume that the sign in problem 1 is on when the follower is off the cam. How would this affect the dwell angles?

   The dwell angles would be reversed:

   $$\theta = 240^0 = \frac{4\pi}{3} \text{ rad. and } \beta = 120^0 = \frac{2\pi}{3} \text{ rad.}$$

ANSWERS TO PROBLEMS - ROTARY CAMS

4. Make a sketch of the cam in problem 3.


"ON" DWELL ANGLE θ
θ = 240°
"OFF" DWELL ANGLE β
β = 120°

HOWEVER, LIGHT IS ON DURING β.

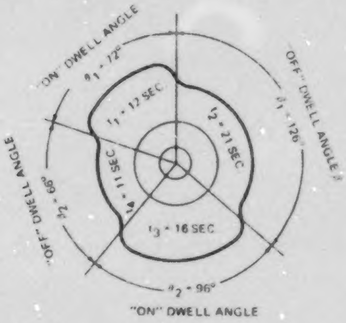
5. A certain timing cam has an on dwell angle of 90^0. What is the RPM of the cam if the on dwell time is 3.5 sec. ?

$$\omega_c = \frac{\theta}{6t_{on}} = \frac{90}{6 \times 3.5} = 4.28 \text{ RPM}$$

6. A single cam is to be used with a 1.0 RPM timing motor to switch on an electric sign. The sign is to be on for 12 sec, off for 21 sec, then on for 16 sec, and off for 11 sec each minute. Sketch a cam that would perform this job. Show the dwell times and angles.

$\theta_1 = 6\omega_c t_1 = 6 \times 1 \times 12 = 72^\circ$ $\beta_1 = 6\omega_c t_2 = 6 \times 1 \times 21 = 126$

$\theta_2 = 6\omega_c t_3 = 6 \times 1 \times 16 = 96^\circ$ $\beta_2 = 6\omega_c t_4 = 6 \times 1 \times 11 = 66$


"ON" DWELL ANGLE
θ1 = 72°
t1 = 12 SEC
"OFF" DWELL ANGLE β
β1 = 126°
t2 = 21 SEC
t3 = 16 SEC
θ2 = 96°
"ON" DWELL ANGLE
t4 = 11 SEC
β2 = 66°
"OFF" DWELL ANGLE

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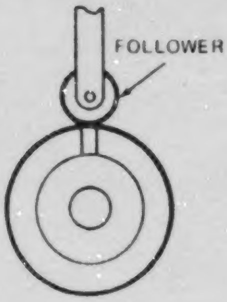
ANSWERS TO PROBLEMS - ROTARY CAMS

7. Suppose that you have a 1/4 in. OD cam follower roller that is to be used with a cam having R = 3/4 in. and r = 1/2 in. The cam rotates at 2.0 RPM. Is it possible to have a dwell time so short that the roller cannot possible follow the cam? Explain your answer using sketches to illustrate the conditions.



If the "off" dwell time corresponds to an arc length of less than 1/4 in., the follower cannot follow the cam:

$$C = 2\pi\, R = 6.28 \times 0.75 = 4.7 \text{ in.}$$

So the minimum possible "off" dwell time is:

$$\frac{4.7\text{ in.}}{120\text{ sec}} \qquad \frac{0.25\text{ in.}}{t_{off}}$$

$$t_{off} = 6.4 \text{ sec. minimum}$$

8. Discuss how follower float and bounce affect the on and off dwell times of a cam application.

   Float tends to reduce the off dwell time and increase the on dwell time. Bounce does not affect dwell time but does affect follower travel.

DRIVES
UNIT IV

TEST ANSWERS

1. a. 5
   b. 7
   c. 2
   d. 3
   e. 6
   f. 8
   g. 1
   h. 4

2. A. $\omega_L = 1700 \text{ X } \frac{2.5}{4} = 1062.5$ RPM

   B. $\omega_L = (1.00 - .05)\ {}_L = .95 \text{ X } 1062.5 = 1009.4$ RPM

   C. A toothed belt drive overcomes the inherent slippage of a belt drive.

3. The toothed belt lends itself well to this type application. However, the bead chain may also be used in this configuration for very light loads and slow speeds.

4. A. $\omega 2 = \omega 1 \frac{r_1}{r_2} = 500 \text{ X } \frac{5}{3} = 83\text{-}1/3$ RPM

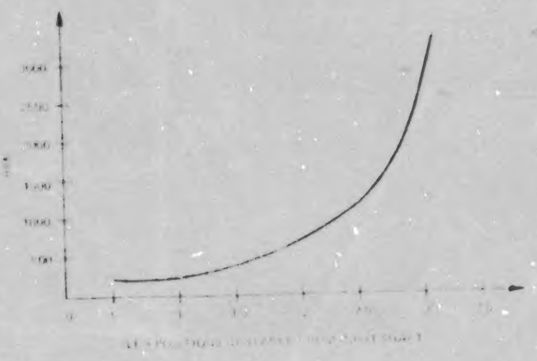
   (r_1 = 3 in. and r_2 = .5 in.)

   $\omega 2 = \omega_1 \frac{r_1}{r_2} = \frac{3}{5} = 3000$ RPM

   $\therefore$ Range of ω_2 is 83-1/3 RPM to 3000 RPM

TEST ANSWERS

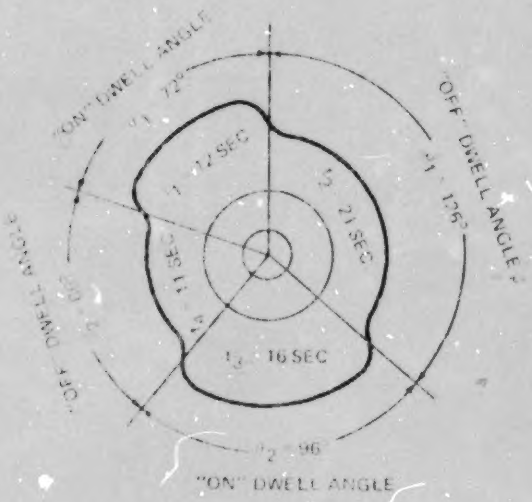
B.



5. A.

$$\theta_1 = 6\omega_c t_1 = 6 \times 1 \times 12 = 72^\circ \qquad \beta_1 = 6\omega_c t_2 = 6 \times 1 \times 21 = 126^\circ$$

$$\theta_2 = 6\omega_c t_3 = 6 \times 1 \times 16 = 96^\circ \qquad \beta_2 = 6\omega_c t_4 = 6 \times 1 \times 11 = 66^\circ$$


"ON" DWELL ANGLE
θ1 = 72°
t1 = 12 SEC
t2 = 21 SEC
"OFF" DWELL ANGLE β
β1 = 126°
t3 = 16 SEC
θ2 = 96
"ON" DWELL ANGLE
t4 = 11 SEC
"OFF" DWELL ANGLE β
β2 = 66°

B. Float tends to reduce the off dwell time and increase the on dwell time. Bounce does not affect dwell time but does affect follower travel.

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MECHANICAL DEVICES

UNIT V

LINKAGES

LINKAGES

UNIT V

OBJECTIVES

After completing this unit, the student should be able to calculate missiong components from given components and construct examples of the three classes of levers. This knowledge will be shown by completing an assignment sheet, lab procedures, problems and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with linkages to their definitions.
2. Calculate loads on a class one lever.
3. Calculate various components of compound class-one lever.
4. Evaluate class-two lever components from a given component value.
5. Discuss difference between class-two and class-three levers.
6. Observe combinations of levers through rocker-arms and bell-cranks.
7. Demonstrate the ability to
    a. Examine the results of changing magnitudes of class-one lever components.
    b. Analyze differences between calculated and measured values of compound levers.
    c. Compute the lever-arm ratio and compare with the force ratio for class-two lever.
    d. Construct class-three levers.
    e. Show combinations of levers by building bell-cranks and rocker-arms.

LINKAGES

UNIT V

SUGGESTED ACTIVITIES

I. Instructor
  - A. Provide student with objective sheet.
  - B. Provide students with procedure sheet and LINKAGES text.
  - C. Make transparencies.
  - D. Discuss unit and specific objectives.
  - E. Discuss labs and problems from LINKAGES.
  - F. Demonstrate differences between classes of levers.
  - G. Assist students in analyzing classes of levers.
  - H. Assist students in lab calculations.
  - I. Give test.

II. Student
  - A. Read objective sheet.
  - B. Complete procedure sheets
  - C. Take test.

LINKAGES

UNIT V

INSTRUCTIONAL MATERIAL

I. Included in this unit:

   A. Objective sheet.

   B. Procedure sheet.

   C. Test.

   D. Answers to assignment sheets.

   E. Answers to test.

II. References

   A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

   B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

   C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

   A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development,1981.

LINKAGES

UNIT V

PROCEDURE SHEET

_____1. Complete Assignment Sheet #1 - using Experiments 1-5, "Linkages", Pages 1-33.

_____2. Study Class-One Levers, "Linkages", Pages 1-7.

_____3. Do Lab Procedures, Pages 4-5.

_____4. Stop Have your instructor review your results. If necessary redo Step 3.

_____5. Complete Problems, "Linkages", Pages 6-7.

_____6. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 7. Otherwise repeat Steps 2, 5 and 6.

_____7. Write An informal lab report for Class-One Levers. Use the informal format described on Page 207, "Drives".

_____8. Study Compound Levers, "Linkages", Pages 8-10.

_____9. Do Lab Procedures, Pages 10-11.

____10. Stop Have your instructor review your results. If necessary redo Step 9.

____11. Complete Problems, "Linkages", Page 12.

____12. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 13. Otherwise repeat Steps 8, 11 and 12.

____13. Write An informal lab report for Compound Levers. Use the informal format described on Page 207, "Drives".

____14. Study Class-Two Levers, "Linkages", Pages 13-16.

____15. Do Lab Procedures, "Linkages", Pages 16-18.

____16. Stop Have your instructor review your results. If necessary redo Step 15.

____17. Complete Problems, "Linkages", Pages 18-19.

PROCEDURE SHEET

____18.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 19. Otherwise repeat Steps 14, 17 and 18.
____19.	Write	An informal lab report for Class-Two Levers. Use the informal format described on Page 207, "Drives".
____20.	Study	Class-Three Levers, "Linkages", Pages 21-23.
____21.	Do	Lab Procedures, "Linkages", Pages 23-24.
____22.	Stop	Have your instructor review your results. If necessary redo Step 21.
____23.	Complete	Problems, "Linkages", Pages 25-26.
____24.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 25. Otherwise repeat Steps 20, 23 and 24.
____25.	Write	An informal lab report for Class-Three Levers. Use the informal format described on Page 207, "Drives".
____26.	Study	Rocker Arms and Bell Cranks, "Linkages", Pages 27-30.
____27.	Do	Lab Procedures, "Linkages", Pages 31-32.
____28.	Stop	Have your instructor review your results. If necessary redo Step 27.
____29.	Complete	Problems, "Linkages", Page 33.
____30.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 31. Otherwise repeat Steps 26, 29 and 30.
____31.	Write	An informal lab report for Rocker Arms and Bell Cranks. Use the informal format described on Page 207, "Drives".
____32.	Turn-In	All lab reports before continuing.
____33.	Review	Chapters 1, 2, 3, 4 and 5, "Linkages".

PROCEDURE SHEET

34. Complete — Unit Test - Linkages

35. Stop — Have your instructor evaluate the Unit Test - Linkages. If your instructor is satisfied with your performance, continue on to Unit VI. Otherwise review the areas suggested by your instructor and repeat Steps 34 and 35.

LINKAGES

UNIT V

ASSIGNMENT SHEET #1 - TERMS AND DEFINITIONS ASSOCIATED WITH LINKAGE

Using Pages 1-33, "Linkages", write a definition for each of the following terms:

1. Lever -
2. Effort -
3. Wright -
4. Moment of Force -
5. Equilibrium -
6. Mechanical Advantage -
7. Velocity Ratio -
8. Compound Class-One Lever -
9. Lever Efficiency -
10. Class-Two Lever -
11. Reaction Force -
12. Class-Three Lever -
13. Fractional Mechanical Advantage -
14. Center of Gravity -
15. Torque -
16. Rocket Arm -
17. Bell Crank -

LINKAGES

UNIT V

TEST

NAME____SCORE__________

1. Match the terms associated with linkage to their definitions. Mark the correct number in the blank.

_____a. Point where weight is concentrated.

_____b. A lever where the direction of motion of the output force is in the same direction of motion as the input force.

_____c. A device which transmits motion from a link traveling in one direction to another link which is to be moved in a different direction.

_____d. Work done at load end of lever divided by work done at input end of lever.

_____e. Two class-one levers connected together by a rigid link.

_____f. Distance through which the input force moves divided by distance through which the output force moves.

_____g. Product of the force vector and its perpendicular distance to the point.

_____h. Resistance.

_____i. Balance obtained when the moments about the center of moments are equal.

_____j. Force applied.

_____k. Rigid bar free to rotate about a bearing known as the fulcrum.

_____l Ratio of the output force to the input force.

_____m. A class-one lever in which the fulcrum is located between the applied force and the resultant force.

1. Lever
2. Effort
3. Bell Crank
4. Compound Class-One Lever
5. Rocker Arm
6. Center of Gravity
7. Class-Three Lever
8. Mechanical Advantage
9. Equilibrium
10. Weight
11. Fractional Mechanical Advantage
12. Reaction Force
13. Lever Efficiency
14. Velocity Ratio
15. Moment of Force
16. Class-Two Lever

TEST

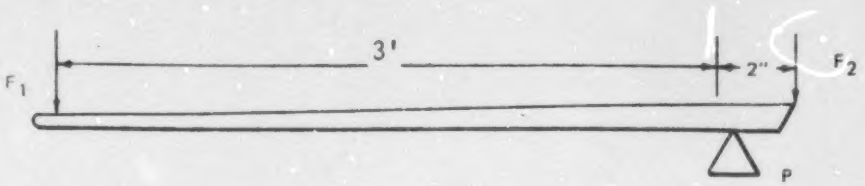
_____n. More force must be applied than is to be moved or lifted.

_____o. Force which fulcrum must be capable of supporting in a class-two lever.

_____p. A lever for which the effort or input force is closer to the fulcrum than is the load or output force.

2. A crowbar (fig 1) has a solid support at P, and a load F_2 is to be lifted by a man's push at F_1. If for F_1 is 75 lbs., what load can be lifted for the dimensions shown?

FIGURE 1



3. It is desired to transmit motion by means of a class-one lever. The driver is attached 50 mm from the fulcrum and moves 4 cm. If the output motion desired is 2 cm, where would the output be attached?

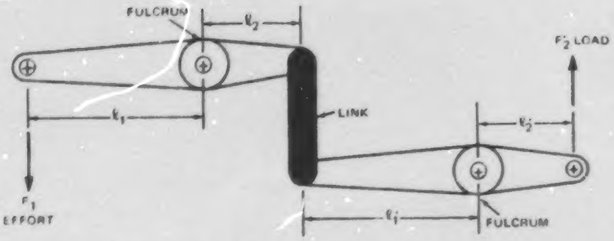
4. A compound lever of the type shown in figure 2 has an input force of 110 oz. The lever arm lengths are:

ℓ_1 = 1.2 ft., ℓ_2 = 4 in., ℓ_1' = 11 in., and ℓ_2' = 3.5 in.

What is the output force?

TEST

FIGURE 2


FULCRUM
ℓ_2
F_2' LOAD
LINK
ℓ_1
ℓ_2'
F_1
EFFORT
ℓ_1'
FULCRUM

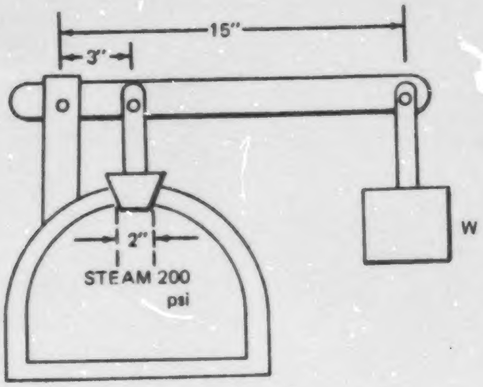
5. If the input in problem 4 moves a short distance with a velocity of 1.8 ft/sec, how fast does the link move?

6. What is the total mechanical advantage in problem 4?

TEST

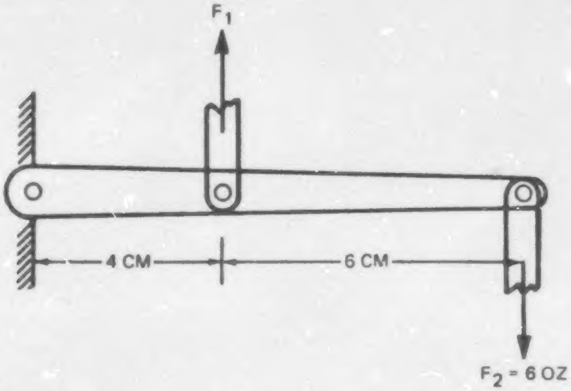
7. A safety valve on a boiler, figure 3, has a 3-inch diameter and a steam pressure of 300 lb/in^2. If the lever arm is 15 inches long, and the valve is 3 inches from the pivot point, what is the value of W that is required?

FIGURE 3



8. Is the lever shown in figure 4 a class-three lever, or is it a class-two lever? Explain in detail your answer.

FIGURE 4



TEST

9. Assume that a rocker-arm is 3 inches long with the pivot point 1 1/4 inch from the load side. The input force occurs 2000 times per minute and travels 1/2 inch. (a) What is the average angular speed in radians per second of the rocker arm? (b) What is the average linear speed of the input force and of the output force?

10. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary ask your instructor about study requirements and possible retesting.

MATHEMATICAL EXPRESSIONS

$F_2 \times \ell_2 = F_1 \times \ell_1$

$MA = \frac{F_2}{F_1}$

$VR = \frac{S_1}{S_2}$

$M_1 = F_1 \ell_1$

$M_2 = F_2 \ell_2$

$M_1 = M_2$ or $F_1 \ell_1 = F_2 \ell_2$

$\frac{F_2}{F_1} = \frac{\ell_1}{\ell_2}$

$MA = \frac{F_2}{F_1} = \frac{\ell_1}{\ell_2}$

$f = F_1 \frac{\ell_1}{\ell_2}$

$f = F'_2 \frac{\ell'_2}{\ell'_1}$

$\frac{F'_2}{F_1} = \left(\frac{\ell_1}{\ell_2}\right)\left(\frac{\ell'_1}{\ell'_2}\right)$

$MA_T = (MA_1)(MA_2)$

$F_2 \times \ell_2 = F_1 \times \ell_1$

$F_y \times \ell_2 = F'_y \times \ell_1$

$S_1/S_2 = \ell_1/\ell_2$

$VR = \frac{S_1}{S_2} = \frac{\ell_1}{\ell_2} = \frac{F_1}{F_2}$

$eff = \frac{MA}{VR}$

$MA = \frac{F_2}{F_1}$

$\ell_2 \times F_2 \sin \theta = \ell_1 \times F_1 \sin \Theta$

LINKAGES

UNIT V

ANSWERS TO ASSIGNMENT SHEET #1

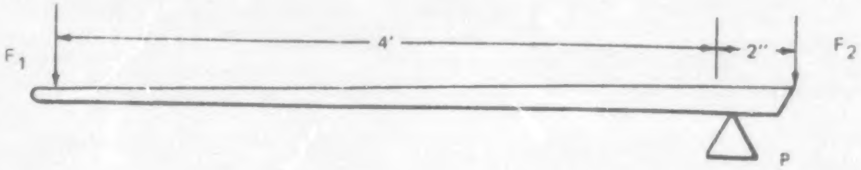
1. Lever - Rigid bar free to rotate about a bearing known as the fulcrum.
2. Effort - Force applied.
3. Weight - Resistance.
4. Moment of Force - Product of the force vector and its perpendicular distance to the point.
5. Equilibrium - Balance obtained when the moments about the center of moments are equal.
6. Mechanical Advantage - Ratio of the output force to the input force.
7. Velocity Ratio - Distance through which the input force moves divided by distance through which the output force moves.
8. Compound Class-One Lever - Two class-one levers connected together by a rigid link.
9. Lever Efficiency - Work done at load end of lever divided by work done at input end of lever.
10. Class-Two Lever - A lever where the direction of motion of the output force is in the same direction of motion as the input force.
11. Reaction Force - Force which fulcrum must be capable of supporting in a class-two lever.
12. Class-Three Lever - A lever for which the effort or input force is closer tothe fulcrum than is the load or output force.
13. Fractional Mechanical Advantage - More force must be applied than is to be moved or lifted.
14. Center of Gravity - Point where weight is concentrated.
15. Torque - See moment of force in experiment 1.
16. Rocker Arm - A class-one lever in which the fulcrum is located between the applied force and the resultant force. The resultant force is in the opposite direction from the applied force.
17. Bell Crank - A device which transmits motion from a link traveling in one direction to another link which is to be moved in a different direction.

LINKAGES

UNIT V

ANSWERS TO PROBLEMS - CLASS-ONE LEVERS

1. A crowbar has a solid support at P, and a load F_2 is to be lifted by a man's push at F_1. If force F_1 is 100 lbs., what load can be lifted for the dimensions shown?



$$F_1 \times \ell_1 = F_2 \times \ell_2$$

$$100 \text{ lbs.} \times 48 \text{ in.} = F_2 \times 2 \text{ in.}$$

$$\frac{100 \text{ lbs.} \times 48 \text{ in.}}{2 \text{ in.}} = F_2$$

$$F_2 = 100 \text{ lbs.} \times 24 \text{ in.} = 2400 \text{ lbs.}$$

2. A bar is placed under a two-ton stone with a fulcrum 16 inches from the point of application. How long will the rest of the lever be in order to raise the stone with a 150-pound pull?

$$F_1 \times \ell_1 = F_2 \times \ell_2$$

$$\ell_1 = \frac{4000 \text{ lbs.} \times 16 \text{ in.}}{150 \text{ lbs.}}$$

$$\ell_1 = 27 \times 16 \text{ in.} = 432 \text{ in.}$$

$$\ell_1 = 35\ 1/2 \text{ ft or } 426 \text{ in.}$$

3. It is desired to transmit motion by means of a class-one lever. The driver is attached 75 mm from the fulcrum and moves 4 cm. If the output motion desired is 1.5 cm, where would the output be attached?

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2}$$

$$\frac{40}{15} = \frac{75}{\ell_2}$$

$$\ell 2 = \frac{75 \text{ mm} \times 15 \text{ mm}}{40 \text{ mm}}$$

$$\ell_2 = 28 \text{ mm}$$

ANSWERS TO PROBLEMS - CLASS-ONE LEVERS

4. A typewriter type bar is 8 in. long on one side of the fulcrum and has 1/2 in. arm to move 90 degrees in 0.1 second. Compute the linear velocity of the type on the end of the 8 in. lever arm.

$s = v^t$

$3.14 = v^t$

$3.14 = \quad _{v}$

0.1

$v = 31.4$ in./sec.

LINKAGES

UNIT V

ANSWERS TO PROBLEMS - COMPOUND LEVERS

1. A compound lever of the type shown in figure 2-2 has an input force of 125 oz. The lever arm lengths are:

$\ell_1 = 1.2$ ft., $\ell_2 = 4$ in., $\ell'_1 = 11$ in., and $\ell'_2 = 3.5$ in.

What is the output force?

$$F_1 \times \ell_1 = F_2 \times \ell_2$$

$$F_2 = \frac{F_1 \times \ell_1}{\ell_2} = \frac{125 \text{ oz.} \times 14.4 \text{ in.}}{4 \text{ in.}} = 450 \text{ oz.}$$

$$F'_2 = \frac{\ell'_1 \times F_2}{\ell'_2} = \frac{11 \text{ in.} \times 450 \text{ oz.}}{3.5 \text{ in.}} = 1413 \text{ oz.}$$

2. What is the link force in problem 1?

$$f = \frac{F_1 \times \ell_1}{\ell_2} = \frac{125 \text{ oz.} \times 14.4 \text{ in.}}{4 \text{ in.}} = 450 \text{ oz.}$$

3. If the input in problem 1 moves a short distance with a velocity of 1.8 ft/sec, how fast does the link move?

$S = \mu t \qquad t = 1$ sec

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2}$$

$$S_2 = \frac{\ell_2 \times S_1}{\ell_1} = \frac{4 \text{ in.} \times 1.8 \text{ ft/sec}}{14.4 \text{ in.}} = .5 \text{ ft/sec.}$$

How fast does the output move in problem 3?

$$\frac{S_2}{S'_2} = \frac{\ell'_1}{\ell_2}$$

$$S'_2 = \frac{S_2 \times \ell_2}{\ell'_1} = \frac{.5 \text{ ft/sec} \times 4 \text{ in.}}{11} = .15 \text{ ft/sec}$$

ANSWERS TO PROBLEMS - COUMPOUND LEVERS

5. What is the total mechanical advantage in problem 1?

$$MA_1 = \frac{F_2}{F_1} = \frac{450}{125} = 3.6$$

$$MA_2 = \frac{F_2}{F_2} = \frac{1413}{450} = 3.14$$

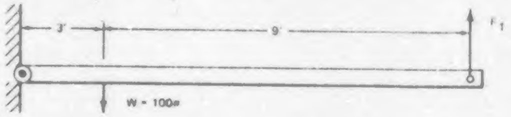
$$MA_T = (MA_1)\ (MA_2) = (3.6)(3.14) = 12.3$$

LINKAGES

UNIT V

ANSWERS TO PROBLEMS - CLASS-TWO LEVERS

1. Assume that a sign hinged to a wall has a length of 2 feet and has an effective weight of 100 pounds when 3 feet from the wall. What upward force F_1 is necessary to support the sign? (see figure 3-7)

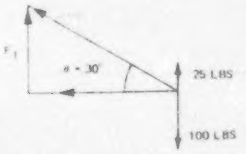


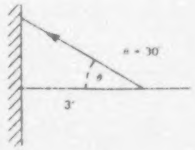
$$F_1 \text{ X } \quad _1 = F_2 \text{ X } \quad _2$$

$$F_1 = \frac{F_2 \text{ X } \quad _2}{\quad _1} = \frac{100 \text{ lbs X } \quad \text{ft}}{12 \text{ ft.}} = 26 \text{ lbs.}$$

2. In the same problem, assume that there is no place to support F_1 in a vertical position, and that a cable is attached to that end of the sign and brought over to the building making an angle of 30° with the horizontal. How much force will the cable be required to support?

NOTE: You already know the vertical component from problem one.





$$\frac{F_1}{X} = \sin 30°$$

$$X = \frac{F_1}{\sin 30°} = \frac{25 \text{ lbs.}}{0.5} = 50 \text{ lbs.}$$

ANSWERS TO PROBLEMS - CLASS-TWO LEVERS

3. A safety valve on a boiler, figure 3-8, has a 2 inch diameter and a steam pressure of 200 lb/in^2. If the lever arm is 15 inches long, and the valve is 3 inches from the pivot point, what is the value of W that is required?

$d = 2$ in. $\quad \text{Area} = \frac{\pi d^2}{4} = \frac{3.14 \times 2 \text{ in.} \times 2 \text{ in.}}{4} = 3.14 \text{ in}^2$

F_1 = Pressure × Area

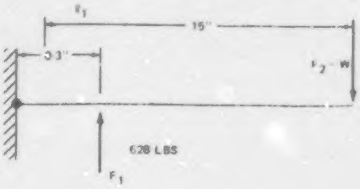
$F_1 = 200 \frac{lb}{in^2} \times 3.14 \text{ in}^2$

$F_1 = 628$ lbs.

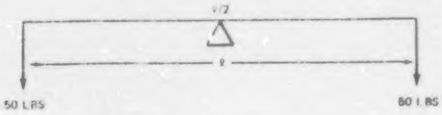
$F_1 \times \ell_1 = F_2 \times \ell_2$

$628 \times 3 \text{ in.} = F_2 \times 15 \text{ in.}$

$W = F_2 = 125.6$ lbs.



4. In the discussion, a problem was solved using the "equivalent vertical pull" of a 50 pound force. Draw a sketch showing that 50 pounds times the "effective lever arm distance" gives identical results.



8

5. In problem 3, if the safety valve moved 1/32 inch, how far does the weight move?

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2} = \frac{F_1}{F_2}$$

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2} \quad \text{where } S_1 = 1/32 \text{ in.} = 0.031 \text{ in.}$$

$$\frac{0.031}{S_2} = \frac{3}{15} \qquad S_2 = 0.155 \text{ in.}$$

ANSWERS TO PROBLEMS - CLASS-TWO LEVERS

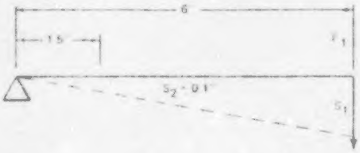
6. Using a class-two lever, where would you place the output on a 6 inch lever to achieve a motion of 0.1 inch if the input motion is 0.4 inch? This may be necessary, for example, if the error in the input motion is 0.4 inch, and your allowable error in a work device is 0.1 inch. Draw a sketch of this lever arrangement.

$S_1 = 0.4$ in. $\qquad S_2 = 0.1$ in.

$S_1 \times \ell_2 = S_2 \times \ell_1$

$0.4 \text{ in.} \times \ell_2 = 0.1 \text{ in.} \times 6 \text{ in.}$

$\ell_2 = \dfrac{0.1 \times 6}{0.4} \qquad \ell_2 = 1.5$ in.



7. Discuss the similarities and the differences between class-one and class-two levers. Give three practical examples of each type.

LINKAGES

UNIT V

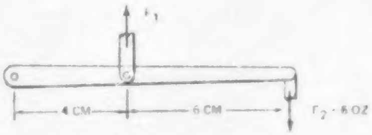
ANSWERS TO PROBLEMS - CLASS-THREE LEVERS

1. Is the lever shown in figure 4-6 a class-three lever, or is it a class-two lever? Explain in detail your answer.

   The lever in figure 4-6 is a class-three lever. Examination reveals that the motion is in the same direction: when F_1 moves up, F_2 also moves up.

2. In figure 4-6 how much pull must be exerted to overcome the load of 6 oz.?

Fig 4-6 Lever for Problem 1



$$F_1 \times \ell_1 = F_2 \times \ell_2$$

$$F_1 \times 4\text{cm} = 6\text{ oz} \times 10\text{ cm} = \frac{6\text{ oz} \times \overset{5}{\cancel{10}}\text{ cm}}{\underset{2}{\cancel{4}}\text{ cm}} = 15\text{ oz.}$$

3. Assume that the lever in problem 2 moves upward (counterclockwise) two degrees. Compute the true distances (arc length) traveled by the points where F_1 and F_2 are attached. Compare the ratio of these distances with the lever-arm ratio.

$$\frac{S_1}{S_2} = \frac{F_1}{F_2} = \frac{\ell_1}{\ell_2}$$

Arc = Radius × sin θ

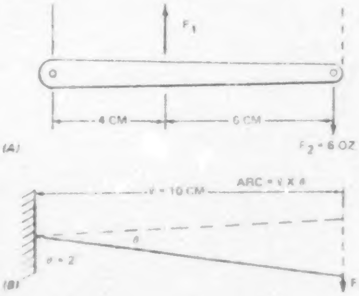
Arc = Radius × angle θ

Arc = 10 cm × 0.035

Arc = 0.35 cm

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2} = \frac{4\text{ cm}}{10\text{ cm}} = 0.40$$

2.5



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ANSWERS TO PROBLEMS - CLASS-THREE LEVERS

4. A crimping tool is pinched together with a pair of forces of 10 pounds each as shown in figure 4-7. What is the force exerted on the connector? What is the force in the link X between the two levers of the crimping tool? Hint: If one side of the tool were placed on the bench, the bench would push with 10 lb.

(a) $F_1 \times \ell_1 = F_2 \times \ell_2$

$10 \text{ lbs.} \times 5 \text{ in.} = F_2 \times 0.5 \text{ in.}$

$F_2 = \frac{10 \text{ lbs.} \times \overset{10}{\cancel{5}} \text{ in.}}{\cancel{0}.\cancel{5} \text{ in.}}$

$F_2 = 100 \text{ lbs.}$

(b) $F_1 \times \ell_1 = F_2 \times \ell_2$

$10 \text{ lbs.} \times 5.5 \text{ in.} = F_2 \times 0.5 \text{ in.}$

$F_2 = \frac{10 \text{ lbs.} \times \overset{11}{\cancel{5}.\cancel{5}} \text{ in.}}{\cancel{0}.\cancel{5} \text{ in.}}$ $F_2 = 110 \text{ lbs.}$

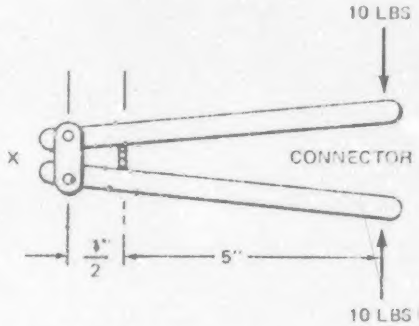
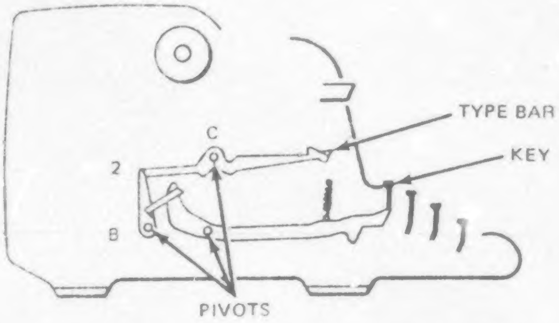


Fig. 4-7 A Crimping Tool

5. Figure 4-8 is a sketch of a typewriter mechanism. Identify the class of the levers that are marked A, B, C. Discuss the relative motion (speed) of point 1 and point 2.

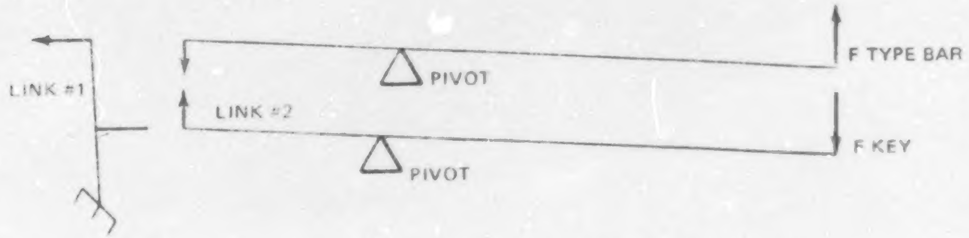
Fig. 4-8 Typewriter Mechanism



A is a class-one lever; B is a class-two lever; and C is a class-one lever. Inspection of figure 4-8 indicates that when point 1 moves up, point 2 moves down, or when point 1 moves down, point 2 moves up.

ANSWERS TO PROBLEMS - CLASS-THREE LEVERS

6. Discuss the transfer of forces between the force applied to the key and the force by the type bar, based on the typewriter sketch. Which of the three lvers (A, B, or C) is used primarily to increase speed?



When F_{key} is applied, the direction of force for link #2 moves up and causes link #1 to move up which makes point 2 move down. Point 2 makes $F_{type\ bar}$ move up. Lever B is used primarily for speed.

7. An eight-inch long lever is pivoted at one end and has its input force one inch from the pivot. Three loads of 2, 3, and 4 ounces are 6, 7, and 8 inches, respectively, from the pivot. What input force is necessary to establish equilibrium?

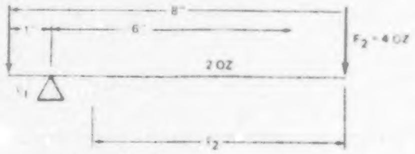
$F_1 \times \ell_1 = F_2 \times \ell_2$

$F_1 \times 1$ in. = 4 oz. × 7 in. + 2 oz. × 6 in.

$F_1 \times 1$ in. = (28 + 12) in./oz.

$F_1 = \frac{40 \text{ in./oz.}}{1 \text{ in.}}$

$F_1 = 40$ oz.



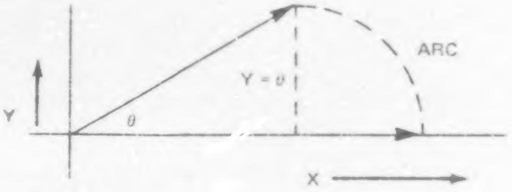
8. In figure 4-1 let the 1-foot distance be X and the 3-foot distance be Y. Assume that the lever rotates through θ degrees. In terms of X, Y, and θ, express the vertical distance and the arc distance that F_1 and F_2 travel.

Arc Distance = $X\theta$

Arc Distance = (1 ft.) (θ)

Vertical Distance $Y = X \sin\theta$

3 ft. = (1 ft.) ($\sin\theta$)

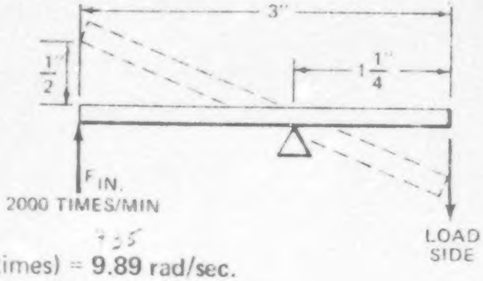


LINKAGES

UNIT V

ANSWERS TO PROBLEMS - ROCKER ARMS AND BELL CRANKS

1. Assume that a rocker-arm is 3 inches long with the pivot point 1 1/4 inch from the load side. The input force occurs 2000 times per minute and travels 1/2 inch. (a) What is the average angular speed in radians per second of the rocker arm? (b) What is the average linear speed of the input force and of the output force?



(a) $\sin\theta = \dfrac{\text{vertical distance}}{\text{horizontal distance}}$

$$\sin\theta = \frac{1/2''}{1\ 3/4''} = 0.286 = 16^\circ\ 40' \simeq 17^\circ$$

$$17^\circ \left(\frac{1\ \text{radian}}{57.3^\circ}\right) = 0.297\ \text{radians}$$

2000 times/minute = 33.3 times/sec.

$$\omega_{\text{angular}} = \frac{\text{radians}}{\text{time}} = \frac{0.297\ \text{rad}}{1\ \text{sec}}\ (33.3\ \text{times}) = \mathbf{9.89\ rad/sec.}$$

(b) Input:

$$\omega_{\text{linear}} = \frac{d}{t} = \frac{1/2''}{1\ \text{sec}}\ (33.3\ \text{times})$$

$$\omega = \mathbf{16.66\ in./sec.}$$

Output:

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2}$$

$$\frac{1/2''}{S_2} = \frac{1\ 3/4''}{1\ 1/4''}$$

$$S_2 = \frac{5''}{14}$$

$$\omega_{\text{linear}} = \frac{\frac{5''}{14}\ (33.3\ \text{times})}{1\ \text{sec}} = \mathbf{11.9\ in./sec.}$$

2. In the previous problem, the input force is increased linearly to 3000 per minute in a time of 30 seconds. (a) What is the linear acceleration of the input and of the output? (b) What is the new linear velocity (speed) of the output?

a. linear accel. of input = velocity X time

ω = 25 in./sec. X 30 sec.

ω_{input} = **750 in./sec.^{2}**

linear accel. of output = velocity X time

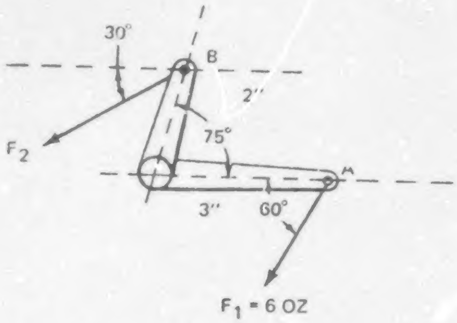
ω = 17.85 in./sec. X 30 sec.

ω_{output} = **535.50 in./sec^2**

b. linear velocity of output $= \dfrac{\frac{5''}{14}\ (50\ \text{times})}{1\ \text{sec.}}$ = **17.85 in./sec.**

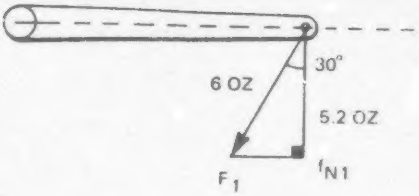
ANSWERS TO PROBLEMS - ROCKER ARMS AND BELL CRANKS

3. A bell-crank has one arm 3 inches long and another 2 inches long which are separated by 75°. A force of 6 oz. is applied at 60° (see figure 5-11) to the 3-inch arm. What force is felt at 30° output at the end of the 2-inch arm?


30°
B
2''
75°
F2
A
3''
60°
F1 = 6 OZ

$F_1 (\cos 30) = f_{N_1}$

$f_{N_1} = 6 \text{ oz. } (0.866) = \mathbf{5.2 \text{ oz.}}$


30°
6 OZ
5.2 OZ
F1
fN1

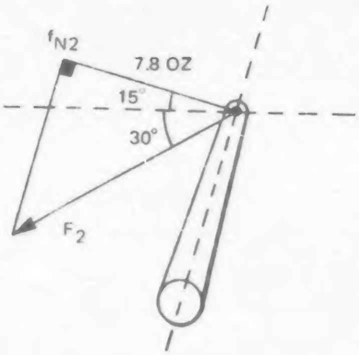
$M_A = 3'' (5.2 \text{ oz.}) = M_B$

$M_A = 15.6 \text{ in.-oz.}$

$M_B = 2'' (f_{N_2})$

$\frac{15.6 \text{ in.-oz.}}{2 \text{ in.}} = f_{N_2}$

$f_{N_2} = 7.8 \text{ oz.}$


fN2
7.8 OZ
15°
30°
F2

$F_2 = \frac{f_{N_2}}{\sin 45°}$

$F_2 = \frac{7.8 \text{ oz.}}{0.707} = \mathbf{11.0 \text{ oz.}}$

LINKAGES

UNIT V

TEST ANSWERS

1. a. 6
   b. 16
   c. 3
   d. 13
   e. 4
   f. 14
   g. 15
   h. 10
   i. 9
   j. 2
   k. 1
   l. 8
   m. 5
   n. 11
   o. 12
   p. 7

2. $75 \times 36 = F_2 \times 2$

$$\frac{75 \times 36}{2} = F_2$$

$$F_2 = 75 \times 18 = 1350 \text{ lbs}$$

3. $\ell_2 = \dfrac{50 \times 20}{40} = 25 \text{ mm}$

4. $F_2{}^1 = \dfrac{\ell 1 \times \ell 1^1}{\ell_2 \times \ell_2 1} \; F_1$

$$F_2{}^1 = \frac{14.4 \times 11}{4 \times 3.5} \times 110 = 1245 \text{ oz.}$$

5. $S = \quad \mu t = 1 \text{ sec}$

$$\frac{S_1 =}{S_2} = \frac{\ell_1}{\ell_2}$$

$$S_2 = \frac{\ell_2 \times S_1}{\ell_1} = \frac{4 \text{ in.} \times 1.8 \text{ ft/sec}}{14.4 \text{ in.}} = .5 \text{ ft/sec.}$$

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TEST ANSWERS

6. $F_2 = \frac{1}{2} \times F_1 = \frac{14.4}{4} \times 110 = 396$ oz.

$$F_2^{1} = \frac{11}{3.5} \times 396 = 1245 \text{ oz.}$$

$$MA_T = (MA_1)(MA_2) = \left(\frac{396}{110}\right)\left(\frac{1245}{396}\right) = 11.3$$

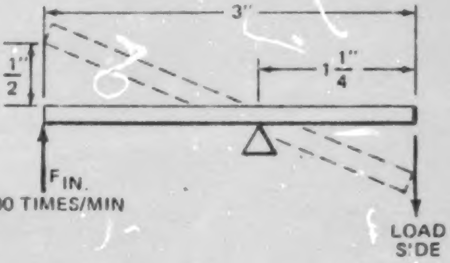
7. $F = PXA = \frac{300 \times \quad \times 3 \times 3}{4} = 2121$ lbs.

$$W = \frac{2121 \times 3}{15} = 4242 \text{ lbs.}$$

8. The lever in figure 4 is a class-three lever. Examination reveals that the motion is in the same direction: when F_1 moves up, F_2 also moves up.

9. (a) $\sin\theta = \frac{\text{vertical distance}}{\text{horizontal distance}}$

$$\sin\theta = \frac{1/2"}{1\ 3/4"} = 0.286 = 16^{o}\ 40' \simeq 17^{o}$$



$$17^{o}\left(\frac{1 \text{ radian}}{57.3^{o}}\right) = 0.297 \text{ radians}$$

2000 times/minute = 33.3 times/sec.

$$\omega_{\text{angular}} = \frac{\text{radians}}{\text{time}} = \frac{0.297 \text{ rad}}{1 \text{ sec}}(33.3 \text{ times}) = 9.89 \text{ rad/sec}$$

(b) Input:

$$\omega_{\text{linear}} = \frac{d}{t} = \frac{1/2"}{1 \text{ sec}}(33.3 \text{ times})$$

$$\omega = 16.66 \text{ in./sec.}$$

Output:

$$\frac{S_1}{S_2} = \frac{\ell_1}{\ell_2}$$

$$\frac{1/2"}{S_2} = \frac{1\ 3/4"}{1\ 1/4"}$$

$$S_2 = \frac{5"}{14}$$

$$\omega_{\text{linear}} = \frac{\frac{5"}{14}(33.3 \text{ times})}{1 \text{ sec.}} = 11.9 \text{ in./sec.}$$

MECHANICAL DEVICES

UNIT VI

LINKING MECHANISMS

LINKING MECHANISMS

UNIT VI

OBJECTIVE

After completing the unit, the student should be able to test a system of linkages to verify that the system is a mechanism and classify its type and practical use. This knowledge will be shown by completing an assignment sheet, lab procedures, experiment problems, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with linking mechanisms to their definitions.
2. Describe the characteristics of a four-bar mechanism.
3. Write the definition of a four-bar mechanism possibility.
4. Write the definition of a crank-rocker mechanism possibility.
5. Describe practical applications for a drag-link mechanism.
6. Discuss the criteria for a double-rocker mechanism.
7. Test a mechanism by using the inequality test to classify its type.
8. Name practical applications for the four versions of the slide crank mechanism.
9. Name practical applications for a toggle mechanism.
10. Name practical applications for a toggle latch mechanism.
11. Demonstrate the ability to
    a. Observe characteristics of a four-bar mechanism.
    b. Calculate values for a crank-rocker mechanism.
    c. Draw a velocity graph of a drag-link mechanism.
    d. Examine the operation of a double-rocker mechanism.

e. Test the link length requirements for each four-bar mechanism.

f. Examine input-output characteristics of the double-rocker mechanism.

g. Observe the mechanical detail of the slider-crank mechanism.

h. Examine characteristics of a toggle linkage.

i. Examine an example of a latching mechanism.

LINKING MECHANISMS

UNIT VI

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with objective sheet.
  B. Provide students with procedure sheet and Drives Text.
  C. Make transparencies.
  D. Discuss unit and specific objectives.
  E. Discuss labs and problems from Drives.
  F. Discuss uses of four-bar, crank-rocker, drag-link, and double-rocker mechanisms.
  G. Demonstrate applications of a toggle mechanisms.
  H. Assist students in constructing linking mechanisms.
  I. Assist students in lab calculations.
  J. Give test.

II. Student

  A. Read objective sheet.
  B. Complete procedure sheets.
  C. Take test.

LINKING MECHANISMS

UNIT VI

INSTRUCTIONAL MATERIAL

I. Included in this unit:

A. Objective sheet.

B. Procedure sheet.

C. Test.

D. Answers to assignment sheets.

E. Answers to test.

II. References

A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development, 1981.

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LINKING MECHANISMS

UNIT VI

PROCEDURE SHEET

_____	1.	Complete	Assignment Sheet #1 - using Experiments 7-13, 29 and 30, "Linkages", Pages 40-92 and 199-210.
_____	2.	Study	Four-Bar Introduction, "Linkages", 40-49.
_____	3.	Do	Lab Procedures, Pages 44-48.
_____	4.	Stop	Have your instructor review your results. If necessary redo Step 3.
_____	5.	Complete	Problems, "Linkages", Page 49.
_____	6.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 7. Otherwise repeat Steps 2, 5 and 6.
_____	7.	Write	An informal lab report for Four-Bar Introduction. Use the informal format described on Page 207, "Drives".
_____	8.	Study	Crank-Rocker Mechanisms, "Linkages", Pages 50-54.
_____	9.	Do	Lab Procedures, Pages 55-57.
____	10.	Stop	Have your instructor review your results. If necessary redo Step 9.
____	11.	Complete	Problems, "Linkages", Page 58.
____	12.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 13. Otherwise repeat Steps 8, 11 and 12.
____	13.	Write	An informal lab report for Crank-Rocker Mechanisms. Use the informal format described on Page 207, "Drives".
____	14.	Study	Drag-Link Mechanism, "Linkages", Pages 59-62.
____	15.	Do	Lab Procedures, "Linkages", Pages 62-64.
____	16.	Stop	Have your instructor review your results. If necessary redo Step 15.
____	17.	Complete	Problems, "Linkages", Page 65.

PROCEDURE SHEET

____18.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 19. Otherwise repeat Steps 14, 17 and 18.
____19.	Write	An informal lab report for Drag-Link Mechanism. Use the informal format described on Page 207, "Drives".
____20.	Study	Double-Rocker Mechanism, "Linkages", Pages 66-68.
____21.	Do	Lab Procedures, "Linkages", Pages 68-70.
____22.	Stop	Have your instructor review your results. If necessary redo Step 21.
____23.	Complete	Problems, "Linkages", Pages 71-72.
____24.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 25. Otherwise repeat Steps 20, 23 and 24.
____25.	Write	An informal lab report for Double-Rocker Mechanism. Use the informal format described on Page 207, "Drives".
____26.	Study	Four-Bar Summary, "Linkages", Pages 73-77.
____27.	Do	Lab Procedures, "Linkages", Page 78.
____28.	Stop	Have your instructor review your results. If necessary redo Step 27.
____29.	Complete	Problems, "Linkages", Page 79.
____30.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 31. Otherwise repeat Steps 26, 29 and 30.
____31.	Write	An informal lab report for Four-Bar Summary. Use the informal format described on Page 207, "Drives".
____32.	Study	Four-Bar Problem, "Linkages", Pages 80-83.
____33.	Do	Lab Procedures, "Linkages", Page 83.
____34.	Stop	Have your instructor review your results. If necessary redo Step 33.

PROCEDURE SHEET

____35. Complete Problems, "Linkages", Page 84.

____36. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 37. Otherwise repeat Steps 32, 25 and 36.

____37. Write An informal lab report for Four-Bar Problem. Use the informal format described on Page 207, "Drives".

____38. Study Slider Crank Mechanisms, "Linkages", Pages 85-89.

____39. Do Lab Procedures, "Linkages", Pages 90-92.

____40. Stop Have your instructor review your results. If necessary redo Step 39.

____41. Complete Problems, "Linkages", Page 93.

____42. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 43. Otherwise repeat Steps 38, 41 and 42.

____43. Write An informal lab report for Slider Crank Mechanisms. Use the informal format described on Page 207, "Drives".

____44. Study Toggle Linkages, "Linkages", Pages 199-202.

____45. Do Lab Procedures, "Linkages", Pages 202-204.

____46. Stop Have your instructor review your results. If necessary redo Step 45.

____47. Complete Problems, "Linkages", Page 205.

____48. Stop Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 49. Otherwise repeat Steps 44, 47 and 48.

____49. Write An informal lab report for Toggle Linkages. Use the informal format described on Page 207, "Drives".

____50. Study Toggle Latching, "Linkages", Pages 206-207.

____51. Do Lab Procedures, "Linkages", Pages 208-210.

PROCEDURE SHEET

____52.	Stop	Have your instructor review your results. If necessary redo Step 51.
____53.	Complete	Problems, "Linkages", Page 210.
____54.	Stop	Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 55. Otherwise repeat Steps 50, 53 and 54.
____55.	Write	An informal lab report for Toggle Latching. Use the informal format described on Page 207, "Drives".
____56.	Turn-In	All lab reports before continuing.
____57.	Review	Chapters 7, 8, 9, 10, 11, 12, 13, 29 and 30, "Linkages".
____58.	Complete	Unit Test - Linking Mechanisms
____59.	Stop	Have your instructor evaluate the Unit Test - Linking Mechanisms. If your instructor is satisfied with your performance, continue on to Unit VII. Otherwise review the areas suggested by your instructor and repeat Steps 58 and 59.

LINKING MECHANISMS

UNIT VI

ASSIGNMENT SHEET #1 - TERMS AND DEFINITIONS ASSOCIATED WITH LINKING MECHANISMS

Using Pages 40-92 and 199-210, "Linkages", write a definition for each of the following terms:

1. Four-Bar Mechanism -
2. Structure -
3. Mechanism -
4. Crank-Rocker Mechanism -
5. Drag-Link Mechanism -
6. Double-Rocker Mechanism -
7. Indefinite Four-Bar Mechanism -
8. Linkage -
9. Crank -
10. Rocker -
11. Coupler -
12. Inversion -
13. Double-Rocker Mechanism -
14. Driving Lever -
15. Driven Lever -
16. Freudenstein Equation -
17. Slider Crank Mechanism -
18. Wristpin -
19. Top Dead Center -
20. Bottom Dead Center -
21. Stroke -

ASSIGNMENT SHEET #1

22. Toggle Linkage -

23. Toggle Latching Mechanism -

24. Toggle Angle -

25. Toggle Stop -

LINKING MECHANISMS

UNIT VI

TEST

NAME____ SCORE__________

1. Match terms associated with linking mechanism to their definitions. Place the correct number in the blank.

_____a. A fixed member which restricts the motion of one of the toggle latching links when it is in the latched position.

_____b. The position of the wristpin when it is at its farthest distance from the crank center.

_____c. A mechanism that has a rotating crank input and a sliding output on a fixed reference.

_____d. The lever that is rigidly attached to the output of the system.

_____e. The angle formed between the two links of a toggle latching mechanism when it is in the latched position.

_____f. Two links joined together in such a way that a small force at the joint produces a large force at the ends of the links.

_____g. The position of the wristpin when it is at its minimum distance from the crank center.

_____h. The equation, used to coordinate the motions of two levers, derived by Freudenstein.

_____i. The result of changing the fixed link (ℓ_o) with the coupler link (ℓ_c) and having the same predictable motion occur.

_____j. The connecting link between the crank and rocker, usually a fixed dimension.

_____k. A four-bar system in which the input and output links rotate a full revolution.

1. Driving Lever
2. Inversion
3. Rocker
4. Linkage
5. Double-Rocker Mechanism
6. Crank-Rocker Mechanism
7. Structure
8. Four-Bar Mechanisms
9. Double-Rocker Mechanism
10. Coupler
11. Crank
12. Indefinite Four-Bar Mechanism
13. Dray-Link Mechanism
14. Mechanism
15. Freudenstein Equation
16. Wristpin
17. Bottom-Dead Center
18. Toggle Linkage
19. Toggle Angle
20. Toggle Stop

TEST

_____l. In general, any combination of four-bars such that the sum of the longest and the shortest links is greater than the sum of the other two links.

_____m. A mechanism having elements pinned or pivoted to each other and having a predictable relative motion.

_____n. A system in which the input link moves in a specified manner but the output link does not, unless gravity, flywheel effect, or spring loading affects it.

_____o. A four-bar system in which the input and output links can only move through limited arcs.

_____p. A system in which the members do not move relative to each other.

_____q. A system in which four rigid links are interconnected in such a way as to allow predictable relative motion.

_____r. The continuously rotating member of a four-bar mechanism.

_____s. The link which oscillates through an arc when linked to the crank.

_____t. A mechanism that latches or holds a load in position.

_____u. The connection to the sliding block.

_____v. The difference between top dead center (TDC) and bottom dead center (BDC).

_____w. The lever that is rigidly attached to the input of the mechanism.

_____x. A four-bar system in which the input link rotates through a complete circle and the output link swings through an arc.

_____y. A system in which one link of a linkage is fixed and the other members have specified motions.

21. Stroke
22. Driven Lever
23. Slide-Crank Mechanisms
24. Top-Dead Center
25. Toggle Latching Mechanism

TEST

2. What are the characteristics of a mechanism as opposed to a structure?

3. What is the test for a four bar mechanism?

4. Verify that a mechanism with lengths $\ell_1 = 0.5"$, $\ell_2 = 2"$, $\ell_c = 6"$, $\ell_o = 5.55"$ is a crank-rocker mechanism.

5. List and discuss three practical applications for the drag-link mechanism.

TEST

6. State criteria necessary for a mechanism to work as a double-rocker.

7. Consider a mechanism having link lengths of: $\ell_1 = 1$ in $\ell_2 = 2$ in

$\ell_o = 2.5$ in $\ell_c = 2$ in

A. Test this mechanism to insure that it is physically possible.

B. Classify the mechanism by type.

8. Name a practical application for each type of slide-crank mechanism shown.

a. ______________________________

TEST

b. ____

c. ____

d. ____

9. List three practical applications of a toggle mechanism.

   a.
   b.
   c.

10. Name two practical applications of a toggle latch mechanism.

    a.
    b.

11. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

MATHEMATICAL EXPRESSIONS

Definition of four-bar mechanism possibility:

$\text{Link}_1 + \text{Link}_2 + \text{Link}_3 > \text{Longest Link}_4$

$\ell_1 < \ell_2 < \ell_c < \ell_o$

$\ell_1 + \ell_c < \ell_2 + \ell_o$

$(\ell_1 + \ell_c)^2 = \ell_2^2 + \ell_o^2 - 2\,\ell_2\ell_o \cos\Theta$

$$\theta = 2 \text{ arc tan } \left(\frac{K \pm \sqrt{K^2 + L^2 - M^2}}{L + M}\right)$$

$K = \sin\Theta$

$$L = \frac{\ell_o}{\ell_2} + \cos\Theta$$

$$M = \frac{\ell_o}{\ell_1}\cos\Theta + \frac{\ell_1^2 + \ell_c^2 + \ell_2^2 + \ell_o^2}{2\ell_1\ell_2}$$

$$\text{Velocity} = \frac{\text{distance}}{\text{length}} = \frac{\text{arc length}}{\text{time}} = r\frac{\Theta}{t} = r\omega$$

$\ell_o < ([\ell_c - \ell_1] + \ell_2)$

$\ell_o < (\ell_c + \ell_2 - \ell_1)$

$$\Theta = \frac{\text{arc length}}{\text{radius}}$$

$$\Theta = \frac{2\pi r}{r} = 2\pi \text{ radians}$$

$$\omega = \frac{\Theta}{t} = \frac{2\pi}{T} = (2\pi)\text{ RPM}$$

$\ell_o + \ell_2 < \ell_1 + \ell_c$

$\ell_c < \ell_1 + \ell_2 - \ell_o$

$\ell_1 < \ell_c + \ell_2 - \ell_o$

$$t_1 = T\left[\frac{180^\circ + \theta - \Theta}{360^\circ}\right]$$

$$t_2 = T\left[\frac{180^\circ - \theta + \Theta}{360^\circ}\right]$$

$$\theta = \text{arc cos}\,\frac{(\ell_1 - \ell_o)^2 - \ell_c^2 + \ell_2^2}{2\ell_2(\ell_1 - \ell_o)}$$

$$\Theta = \text{arc cos}\,\frac{(\ell_1 + \ell_o)^2 - \ell_c^2 + \ell_2^2}{2\ell_2(\ell_1 + \ell_o)}$$

$$t_1 + t_2 = T\left[\frac{180 + \theta - \Theta}{360}\right] + T\left[\frac{180 - \theta + \Theta}{360}\right]$$

$$= T\left[\frac{180 + \theta - \Theta + 180 - \theta + \Theta}{360}\right]$$

$$= T\left[\frac{360}{360}\right] = T$$

MATHEMATICAL EXPRESSIONS

$\ell_c + \ell_2 < \ell_o + \ell_1$

$\ell_c + \ell_1 < \ell_o + \ell_2$

$2\ell_c + \ell_2 + \ell_1 < 2\ell_o + \ell_2 + \ell_1$

$2\ell_c < 2\ell_o$

$\ell_c < \ell_o$

$\ell_2 - \ell_1 < \ell_1 - \ell_2$

$2\ell_2 < 2\ell_1$

$\ell_2 < \ell_1$

$\ell_o < \ell_2 + \ell_1 - \ell_c$

$\ell_o + \ell_c < \ell_2 + \ell_1$

$\ell_o - \ell_2 < \ell_c + \ell_1$

$\ell_o - \ell_c < \ell_2 + \ell_1$

$\ell_c + \ell_2 > \ell_o + \ell_1$

$\ell_c < \ell_o + \ell_1 + \ell_2$

$\ell_1 < -\ell_c + \ell_2 + \ell_o$

$2\ell_1 < 2\ell_2$ or $\ell_1 < \ell_2$

$2\ell_1 < 2\ell_o$ or $\ell_1 < \ell_o$

$\ell_c - \ell_2 + \ell_1 < \ell_o$

$|\ell_c - \ell_2| + \ell_1 < \ell_o < \ell_c + \ell_2 - \ell_1$

$|\ell_c - \ell_1| + \ell_o < \ell_2 < \ell_c + \ell_1 - \ell_o$

$\ell_2 < \ell_o + \ell_1 + \ell_c$

$\ell_1 < \ell_c + \ell_2 - \ell_o$

$\ell_1 < \ell_c - \ell_2 + \ell_o$

$2\ell_1 < 2\ell_c$ or $\ell_1 < \ell_c$

$\ell_o < \ell_c + \ell_2 - \ell_1$

$\ell_2 - \ell_c + \ell_1 < \ell_o$

$\ell_c \cos\alpha - \ell_1 \cos\theta + \ell_o + \ell_2 \cos\Theta = 0$

$\ell_c \sin\alpha - \ell_1 \sin\theta + \ell_2 \sin\Theta = 0$

$\ell_c^2 \cos^2\alpha = (\ell_1 \cos\theta - \ell_o - \ell_2 \cos\Theta)^2$

$\ell_c^2 \sin^2\alpha = (\ell_1 \sin\theta - \ell_2 \sin\Theta)^2$

$K_1 \cos\Theta - K_2 \cos\theta + K_3 = \cos(\Theta - \theta)$

where:

$K_1 = \ell_o/\ell_1$

$K_2 = \ell_o/\ell_2$

$K_3 = (\ell_o^2 + \ell_2^2 - \ell_c^2 + \ell_1^2) / (2\ell_2\ell_1)$

MATHEMATICAL EXPRESSIONS

$$TDC = \ell_1 + \ell_c$$

$$BDC = \ell_c - \ell_1$$

$$\text{Stroke} = TDC - BDC = (\ell_1 + \ell_c)$$

$$- (\ell_c - \ell_1) = 2\ell_1$$

$$\sin \theta = \frac{\sin \Theta}{k}$$

$$d = (\ell_c + \ell_1) - \ell_1 \cos \Theta - \ell_c \cos \theta$$

$$= \ell_1 (1 - \cos \Theta) + \ell_c (1 - \cos \theta)$$

$$d = \ell_1 (1 - \cos \Theta)$$

$$+ \ell_c \left(1 - \sqrt{1 - \frac{\sin^2 \Theta}{k^2}}\right)$$

$$d \cong \ell_1 (1 - \cos \Theta) + \left(\frac{\ell_1^2}{2\ell_c} \sin^2 \Theta\right)$$

$$V_P = \ell_1 \omega \left(\sin \Theta + \frac{\sin^2 \Theta}{2k}\right)$$

$$a_P = \ell_1 \omega^2 \left(\cos \Theta + \frac{\cos 2\Theta}{k}\right)$$

$$\omega_{P_1P_2} = 1 \frac{\omega \cos \Theta}{(k^2 - \sin^2 \Theta)^{1/2}}$$

$$\alpha_{P_1P_2} = \frac{\omega^2 (k^2 - 1) \sin \Theta}{(k^2 - \sin^2 \Theta)^{2/3}}$$

$$\Theta = \text{arc} \cos \frac{1}{(k^2 + 3)^{1/2}}$$

$$\frac{f/2}{F} = \tan \Theta$$

$$\frac{f}{F} = 2 \tan \Theta$$

$$\tan \Theta = \frac{\sin \Theta}{\cos \Theta}$$

$$\frac{f}{F} = 2 \frac{\sin \Theta}{\cos \Theta}$$

$$f \cos \Theta = 2 F \sin \Theta$$

$$f_1 + f_2 = f$$

$$bf_1 = af_2$$

$$F (\ell_3 + \ell_4) = F' (\ell_3)$$

$$F' = F \left(\frac{\ell_3 + \ell_4}{\ell_3}\right)$$

$$f \cong F' \frac{\ell_1 + \ell_2}{\ell_1} \tan \theta$$

$$\frac{f_2}{F} = \tan \Theta$$

$$f_1 = \frac{a}{b} r_2$$

$$\frac{a}{b} f_2 + f_2 = f$$

$$f_2 \left(1 + \frac{a}{b}\right) = f$$

$$f_2 = \frac{f}{1 + a/b}$$

$$\frac{f}{F} = \left(1 + \frac{a}{b}\right) \tan \Theta$$

$$f \cong f \frac{(\ell_3 + \ell_4)(\ell_1 + \ell_2)}{\ell_1 \ell_3} \tan \theta$$

$$f' = f \frac{\ell_1}{S}$$

LINKING MECHANISMS

UNIT VI

ANSWERS TO ASSIGNMENT SHEET #1

1. Four-Bar Mechanisms - A system in which four rigid links are interconnected in such a way as to allow predictable relative motion.
2. Structure - A system in which the members do not move relative to each other.
3. Mechanism - A system in which one link of a linkage is fixed and the other members have specified motions.
4. Crank-Rocker Mechanism - A four-bar system in which the input link rotates through a complete circle and the output link swings through an arc. It is also called a type 1 four-bar mechanism.
5. Dray-Link Mechanism - A four-bar system in which the input and output links rotate a full revolution. It is also called type II four-bar mechanism.
6. Double-Rocker Mechanism - A four-bar system in which the input and output links can only move through limited arcs. It is also called a type III four-bar mechanism.
7. Indefinite Four-Bar Mechanism - A system in which the input link moves in a specified manner but the output link does not, unless gravity, flywheel effect, or spring loading affects it. It is also called a type IV four-bar mechanism.
8. Linkage - A mechanism having elements pinned or pivoted to each other and having a predictable relative motion.
9. Crank - The continuously rotating member of a four-bar mechanism.
10. Rocker - The link which oscillates through an arc when linked to the crank.
11. Coupler - The connecting link between the crank and rocker usually a fixed dimension. This link is also called a connecting rod.
12. Inversion - The result of changing the fixed link (ℓ_0) with the coupler link (ℓ_c) and having the same predictable motion occur.
13. Double-Rocker Mechanism - In general, any combination of four-bars such that the sum of the longest and the shortest links is greater than the sum of the other two links.
14. Driving Lever - The lever that is rigidly attached to the input of the mechanism.

ANSWERS TO ASSIGNMENT SHEET #1

15. Driven Lever - The lever that is rigidly attached to the output of the system.

16. Freudenstein Equation - The equation, used to coordinate the motions of two levers, derived by Freudenstein.

17. Slide-Crank Mechanism - A mechanism that has a rotating crank input and a sliding output on a fixed reference. The output can move in only one dimension.

18. Wristpin - The connection to the sliding block.

19. Top-Dead Center - The position of the wristpin when it is at its farthest distance from the crank center.

20. Bottom-Dead Center - The position of the wristpin when it is at its minimum distance from the crank center.

21. Stroke - The difference between top dead center (TDC) and bottom dead center (BDC),

22. Toggle Linkage - Two links joined together in such a way that a small force at the joint produces a large force at the ends of the links.

23. Toggle Latching Mechanism - A mechanism that latches or holds a load in position.

24. Toggle Angle - The angle formed between the two links of a toggle latching mechanism when it is in the latched position.

25. Toggle Stop - A fixed member which restricts the motion of one of the toggle latching links when it is in the latched position.

LINKING MECHANISMS

UNIT VI

ANSWERS TO PROBLEMS - FOUR-BAR INTRODUCTION

1. What is a four-bar mechanism?

   A system in which four rigid links are interconnected in such a way as to allow predictable relative motion.

2. What are the characteristics of a mechanism as opposed to a structure?

   A structure is a system in which the members cannot move in a predictable relative motion. The only motion that can occur is if one or more of the links is deformed. A mechanism is when one link of a linkage is fixed and the other links have specified motion.

3. How can you test to be sure that four given link dimensions can be connected into a four-bar mechanism?

   By adding the smallest link lengths and comparing the sum to the longest link length to determine the mechanism's possibility. The sum of the shorter links must be great than the longest link.

4. Test each of the following link dimension sets for possibility in a four-bar mechanism.

A) $\ell_o = 2$ in., $\ell_1 = 2$ in., $\ell_c = 6$ in., $\ell_2 = 1$ in.

$\ell_o + \ell_1 + \ell_2 > \ell_c$

$2'' + 2'' + 1'' > 6''$

$5'' \ngtr 6''$ Mechanism is **NOT** possible

B) $\ell_o = 6$ in., $\ell_1 = 2$ in., $\ell_c = 4$ in., $\ell_2 = 2$ in.

$\ell_1 + \ell_c + \ell_2 > \ell_o$

$2'' + 4'' + 2'' > 6''$

$8'' > 6''$ Mechanism is possible

C) $\ell_o = 6$ in., $\ell_1 = 1$ in., $\ell_c = 3$ in., $\ell_2 = 2$ in.

$\ell_1 + \ell_c + \ell_2 > \ell_o$

$1'' + 3'' + 2'' > 6''$

$6'' \ngtr 6''$ Mechanism is **NOT** possible

ANSWERS TO PROBLEMS - FOUR-BAR INTRODUCTION

D) $\ell_o = 5$ in., $\ell_1 = \frac{3}{4}$ in., $\ell_c = 2$ in., $\ell_2 = 1$ in.

$\ell_1 + \ell_c + \ell_2 > \ell_o$

$\frac{3}{4}'' + 2'' + 1'' > 5''$

$3\frac{3}{4}'' \ngtr 5''$ Mechanism is **NOT** possible

E) $\ell_o = 4$ in., $\ell_1 = 2$ in., $\ell_c = 1$ in., $\ell_2 = 1\frac{1}{2}$ in.

$\ell_1 + \ell_c + \ell_2 > \ell_o$

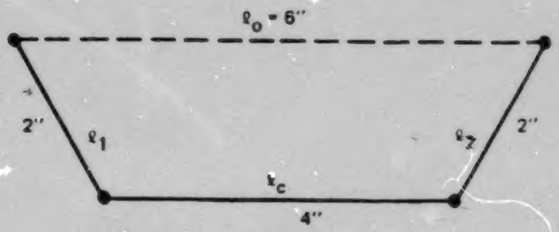
$2'' + 1'' + 1\frac{1}{2}'' > 4''$

$4\frac{1}{2}'' > 4''$ Mechanism is possible.

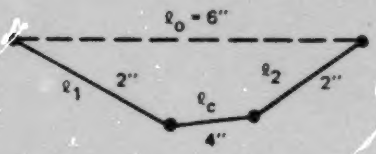
5. Make a sketch of the mechanisms in problem 4 which are possible.

(b) $\ell_o = 6''$, $\ell_1 = 2''$,
$\ell_c = 4''$, $\ell_2 = 2''$

ℓ_o = frame link
ℓ_c = coupling link



(e) $\ell_o = 4''$, $\ell_1 = 2''$,
$\ell_c = 1''$, $\ell_2 = 1\frac{1}{2}''$



6. Tell how each mechanism in problem 5 would act if ℓ_1 rotates at a constant rate clockwise.

(A) Mechanism (B) would function as a double-rocker. ℓ_1 would not be able to rotate a full 360° since ℓ_c plus ℓ_2 equal the distance between the fixed ends.

(B) Mechanism (E) would also function as a double-rocker. The arc ℓ_1 could move through and would be even less than the arc in (B) because ℓ_2 plus ℓ_1 is 1/2" less than ℓ_o.

LINKING MECHANISMS

UNIT VI

ANSWERS TO PROBLEMS - CRANK-ROCKER MECHANISMS

1. Assume that the crank rotation of the mechanism used by you in the experiment was rotating clockwise at 60 RPM. What is the time required for the rocker to move to the left? What is the time needed for its return movement to the right?

LAW OF COSINES

$\angle a = \angle x - \angle b$

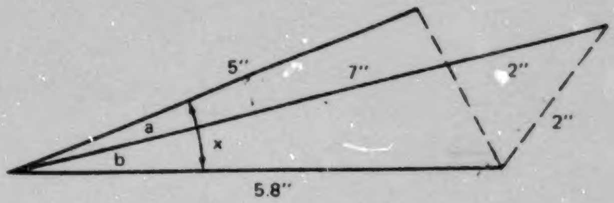
$\angle x = \arccos \left[\frac{5^2 + 5.8^2 - 2^2}{2(5.8)(5)} \right]$

$\angle x = 18°30'$ $\boxed{19.8}$

$\angle b = \arccos \left[\frac{7^2 + 5.8^2 - 2^2}{2(5.8)(7)} \right]$

$\angle b = 14°\,40'$

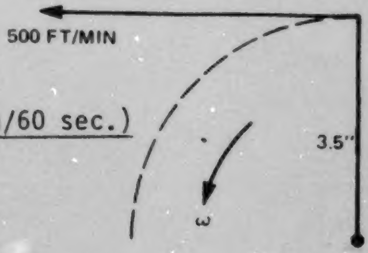
$\angle a = 4°50' = 4.83°$ 5.3



Time for left motion of $\ell_2 = \frac{180 + 4.83}{360} \times 1 = \mathbf{0.513\ sec.}$

Time for right motion of $\ell_2 = \frac{180 - 4.83}{360} \times 1 = \mathbf{0.486\ sec.}$

2. What must be the rotational speed in RPM of a crank 3.5 inches in length if its linear velocity is 500 feet/minute?



Linear velocity = Radius X Angular velocity

500 ft/min. = 3.5" X Angular velocity

$\text{Angular velocity} = \frac{500\ \text{ft/min.}\ (12\ \text{in/ft.})\ (1\ \text{min/60 sec.})}{3.5"}$

$\text{Angular velocity} = \frac{100\ \text{in/sec}}{3.5"} = 28.6\ \text{rad/sec}$

(28.6 rad/sec) (60 sec/min) (rev/6.28 rad) = 273 RPM

ANSWERS TO PROBLEMS - CRANK-ROCKER MECHANISMS

3. The crank described in problem 2 starts at rest with an angular acceleration of 3 radians/second /second. If the acceleration is constant, what is the angular velocity after 7 seconds? What is the linear velocity of a point 3.5 inches from the center at this time? What was the average velocity of this point?

Angular velocity after 7 sec. $= (3 \text{ radians-sec}^2)\ (7 \text{ sec})$

$= 21$ radians-sec.

Linear velocity = radius X angular velocity

= 3.5" X 21 radians-sec (rev-6.28 rad) (21.95"-rev)

= 257.25 in-sec (1 ft-12 in) (60 sec-1 min) = 1280 ft-min

$$\text{Average velocity} = \frac{\text{present velocity - starting velocity}}{2}$$

$$= \frac{1280 \text{ ft-min} \quad 0 \text{ ft-min}}{2} = 640 \text{ ft-min}$$

4. Using equation 8.4, compute one set of angular positions of the crank and rocker used during this experiment. Be sure the angles you use correspond to those of figure 8-4. Compare the computed values with the observed values and comment on the differences.

$K = \sin \Theta$

$K = \sin 60°$

$K = 0.866$

$L = \frac{\ell_o}{\ell_2} + c$ [illegible]

$L = \frac{5.8''}{2''} + \cos 60°$

$L = 2.9 + 0.5$

$L = 3.4$

$$M = \frac{\ell_o}{\ell_1} \cos\Theta + \frac{\ell_1^2 + \ell_c^2 + \ell_2^2 + \ell_o^2}{2\ell_1\ell_2}$$

$$M = \frac{5.8''}{1''} \cos 60° + \frac{(1'')^2 + (6'')^2 + (2'')^2 + (5.8'')^2}{2(1'')(2'')}$$

$$M = 5.8(0.5) + \frac{1 + 36 + 4 + 33.64}{4}$$

$$M = 2.9 + \frac{74.64}{4} = 21.6$$

$$\theta = 2 \text{ arc tan} \left[0.866 + \left(\frac{\sqrt{(0.866)^2 + (3.4)^2 - (21.6)^2}}{3.4 + 21.6} \right) \right]$$

$$= 2 \text{ arc tan } [0.85]$$

$$= 2\,(40°22')$$

$$\theta = 80°44'$$

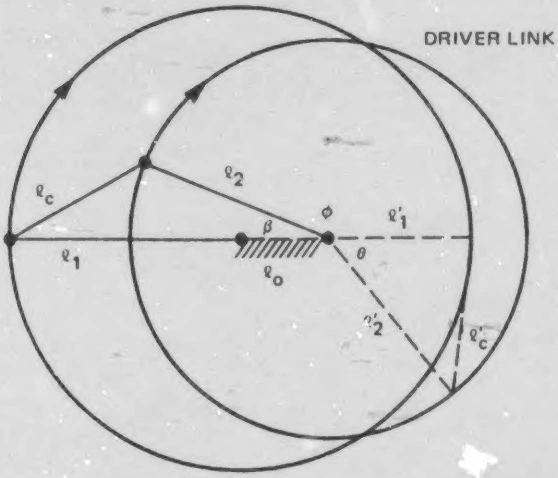
The measured value of ϕ was 76°, the computed value was 80° 44'. This small difference is mainly the result of the slip of the linkage when the crank was rotated through a complete revolution.

LINKING MECHANISMS

UNIT VI

ANSWERS TO PROBLEMS - DRAG-LINK MECHANISMS

1. Figure 9-3 has linkages with the following lengths: $\ell_o = 4$ in., $\ell_1 = 10.5$ in., $\ell_c = 7$ in., and $\ell_2 = 9$ in. ℓ_o is the fixed link and ℓ_2 is the driver. How many degrees must crank ℓ_2 rotate to carry crank ℓ_1 from the extended colinear position to the overlapping colinear position.



$$\angle\beta = \text{arc cos}\,\frac{(10.5+4)^2 - 49 + 81}{2(9)\,(10.5+4)}$$

$$\angle\beta = \text{arc cos}\,\frac{243}{261}$$

$$\angle\beta = \text{arc cos}\,0.930$$

$$\beta = 21°33'$$

$$\angle\theta = \text{arc cos}\,\frac{(10.5-4)^2 - 49 + 81}{2(9)\,(10.5-4)}$$

$$\angle\theta = \text{arc cos}\,\frac{42.25+32}{117}$$

$$\angle\theta = \text{arc cos}\,\frac{74.25}{117}$$

$$\angle\theta = \text{arc cos}\,0.6350$$

$$\theta = 50°35'$$

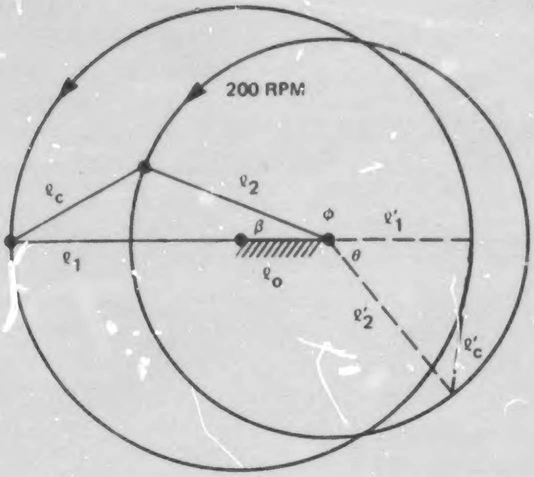
$$\text{Total Arc Rotation} = 180° - \angle\beta + \angle\theta$$

$$= 180° - 21°33' + 50°35' = \boxed{209°02'}$$

Therefore, ℓ_2 must rotate through 209° 02′ to crank ℓ_1 from the extended colinear position to the overlapping colinear position.

ANSWERS TO PROBLEMS - DRAG-LINK MECHANISMS

2. If crank ℓ_2 in problem 1 rotates at 200 RPM, what is the time required for crank ℓ_1 to rotate from the extended colinear position to the overlapping colinear position? What is the time for its return? Assume that crank ℓ_2 rotates in a counterclockwise direction.



$200 \frac{\text{rev}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 3.3 \text{ rev/sec}$ 1 revolution = 0.303 sec

$t_1 = 0.303 \text{ sec} \left[\frac{180° - \theta + \beta}{360°}\right]$

$t_1 = 0.303 \text{ sec} \left[\frac{180° - 50°35' + 21°33'}{360°}\right]$

$t_1 = 0.303 \text{ sec} \left[\frac{150°58'}{360°}\right]$

$t_1 = $ **0.126 sec.**

Return Time = Time of One Revolution - t_1
Return Time = 0.303 - 0.126 sec
Return Time = **0.177 sec.**

ANSWERS TO PROBLEMS - DRAG-LINK MECHANISMS

$600 \frac{\text{rev}}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = 10$ rev/sec   1 revolution = 0.10 sec

$\angle a = \text{arc cot}\ \frac{\ell_o}{\ell_2}$

$\angle a = \text{arc cot}\ \frac{6}{8}$

$\angle a = \text{arc cot}\ 0.750 = 53°08'$

side $H = \sqrt{\ell_o{}^2 + \ell_2{}^2}$

side $H = \sqrt{6^2 + 8^2}$

side $H = \sqrt{36 + 64}$

side $H = \sqrt{100}$

side $H = 10$

$\angle\phi = \text{arc cos}\ \frac{\ell_1{}^2 + H^2 - \ell_c{}^2}{2(\ell_1)(H)}$

$\angle\phi = \text{arc cos}\ \frac{10^2 + 10^2 - 7^2}{2(10)(10)}$

$\angle\phi = \text{arc cos}\ \frac{151}{200}$

$\angle\phi = \text{arc cos}\ 0.755 = 41°01'$

$\angle\beta = 180° - (\angle\phi + \angle a)$

$\angle\beta = 180° - (41°01' + 53°08')$

$\angle\beta = 180° - 94°09'$

$\angle\beta = 85°51'$

Since the drag-link mechanism will rotate 180°, the new position will be a mirror image of the old position. Therefore, angle sigma (σ) will be equal to angle beta (β).

$t_1 = T\ [\frac{\angle\beta + \angle\sigma}{360°}]$

$t_1 = 0.10\ \text{sec}\ [\frac{171°42'}{360°}]$

t_1 = 0.0477 seconds

t_1 = time for link ℓ_2 to rotate from upward to downward position.

$t_2 = T\ [\frac{360° - (\angle\beta + \angle\sigma)}{360°}]$

$t_2 = 0.10\ \text{sec}\ [\frac{188°12'}{360°}]$

t_2 = 0.0523 seconds

t_2 = time for link ℓ_2 to rotate from downward to upward position.

Ratio of $\frac{t_1}{t_2} = \frac{0.0477\ \text{sec}}{0.0523\ \text{sec}} = \mathbf{0.913}$

ANSWERS TO PROBLEMS - DRAG-LINK MECHANISMS

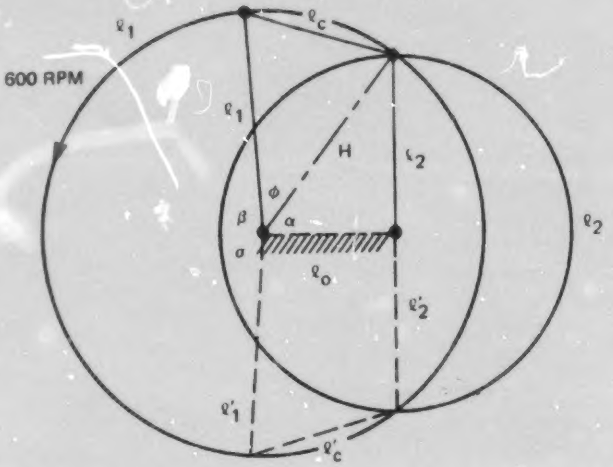
3. List and discuss three practical applications for the drag-link mechanisms.

   One application of the drag-link is in the quick-return mechanism. The reason for using the quick-return mechanism is that some link has a working stroke, that is, the stroke during which the objective of the mechanism, such as cutting metal or form pressing, is being accomplished. On the return stroke of the mechanism, nothing is accomplished except that the mechanism is returned to the beginning of its working stroke. By speeding up the return stroke, the output of the machine can be increased.

   Another application is the steering mechanism in automobiles and direct-to-oscillating motion conversion.

4. Assume that link ℓ_0 and link ℓ_1 shown in figure 9-3 are 6 inches and 10 inches respectively, and that links ℓ_c and ℓ_2 are 7 and 8 inches. If link ℓ_1 is rotating at 600 RPM, how long will it take link ℓ_2 to rotate from a vertical position upward to a vertical position downward? Link ℓ_1 is rotating in a counterclockwise direction. How long will it take for link ℓ_2 to rotate from the vertical downward position back to the upright position? Compute the ratio of these two times.

ℓ_0 = 6 inches
ℓ_1 = 10 inches
ℓ_c = 7 inches
ℓ_2 = 8 inches



ANSWERS TO PROBLEMS - DRAG-LINK MECHANISMS

$$600\,\frac{\text{rev}}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 10\text{ rev/sec} \qquad 1\text{ revolution} = 0.10\text{ sec}$$

$$\angle a = \text{arc cot}\,\frac{\ell_o}{\ell_2}$$

$$\angle a = \text{arc cot}\,\frac{6}{8}$$

$$\angle a = \text{arc cot } 0.750 = 53^\circ 08'$$

$$\text{side H} = \sqrt{\ell_o^{\,2} + \ell_2^{\,2}}$$

$$\text{side H} = \sqrt{6^2 + 8^2}$$

$$\text{side H} = \sqrt{36 + 64}$$

$$\text{side H} = \sqrt{100}$$

$$\text{side H} = 10$$

$$\angle\phi = \text{arc cos}\,\frac{\ell_1^{\,2} + H^2 - \ell_c^{\,2}}{2(\ell_1)\,(H)}$$

$$\angle\phi = \text{arc cos}\,\frac{10^2 + 10^2 - 7^2}{2(10)\,(10)}$$

$$\angle\phi = \text{arc cos}\,\frac{151}{200}$$

$$\angle\phi = \text{arc cos } 0.755 = 41^\circ 01'$$

$$\angle\beta = 180^\circ - (\angle\phi + \angle a)$$

$$\angle\beta = 180^\circ - (41^\circ 01' + 53^\circ 08')$$

$$\angle\beta = 180^\circ - 94^\circ 09'$$

$$\angle\beta = 85^\circ 51'$$

LINKING MECHANISMS

UNIT VI

ANSWERS TO PROBLEMS - DOUBLE-ROCKER MECHANISM

1. The four-bar mechanism shown in figure 10-8 has the following dimensions: $\ell_1 = \ell_o = 14$ in., $\ell_2 = 10$ in., and $\ell_c = 8$ in.

   Will this mechanism work as a double-rocker?

$\ell_c < \ell_o$, $8'' < 14''$

$\ell_2 < \ell_1$, $10'' < 14''$

$\ell_o < \ell_2 + \ell_1 - \ell_c$, $14'' < 10'' + 14'' - 8''$

$\ell_o - \ell_2 < \ell_c + \ell_1$, $14'' - 10'' < 8'' + 14''$

All conditions are satisfied, therefore, the mechanism will work as a double-rocker.

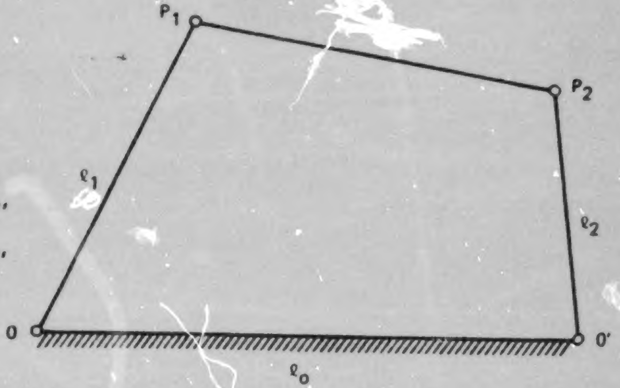
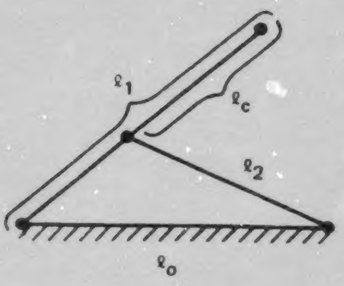


Fig. 10-8 A Four-Bar Mechanism

2. Can the mechanism in figure 10-8 assume an $\ell_1 - \ell_c$ limiting position like that shown in figure 10-3? If so, draw a sketch of the mechanism in that position.

$$\left.\begin{array}{l} \ell_o < \ell_2 + \ell_1 - \ell_c \\ 14'' < 10'' + 14'' - 8'' \end{array}\right\} \text{Yes}$$

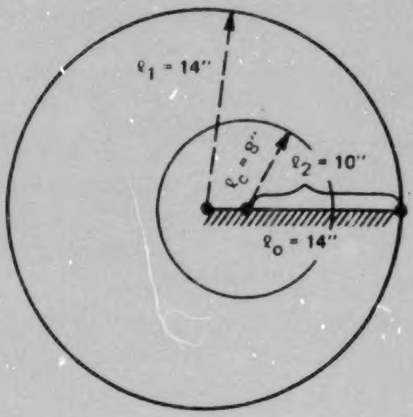


$\ell_1 - \ell_c = 14'' - 8'' = 6''$

ANSWERS TO PROBLEMS - DOUBLE-ROCKER MECHANISM

3. Can the mechanism in figure 10-8 assume an $\ell_0 - \ell_2$ critical position like that shown in figure 10-4? If so, make a sketch of the mechanism in that position.

$$\ell_0 - \ell_2 < \ell_c + \ell_1$$
$$14'' - 10'' < 8'' + 14''$$
$$4'' < 22''$$


$\ell_1 = 14''$
$\ell_c = 8''$
$\ell_2 = 10''$
$\ell_0 = 14''$
$\ell_0 - \ell_2 = 14'' - 10'' = 4''$
ℓ_1 NEVER INTERSECTS ℓ_c

4. Write the inequality that the link lengths in figure 10-9 must satisfy.

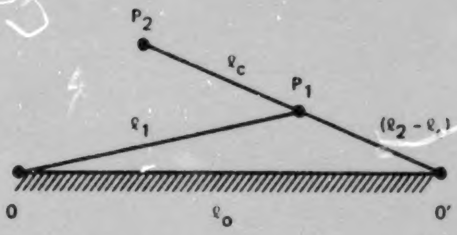

P_2
ℓ_c
P_1
ℓ_1
$(\ell_2 - \ell_c)$
0
ℓ_0
0'

Fig. 10-9 Mechanism for Problem 4

5. Show that your result in problem 4 is identical to inequality 10-5 in the discussion.

$$\ell_0 + \ell_c < \ell_2 + \ell_1$$
$$\ell_0 < \ell_2 - \ell_c$$
$$\text{or } \ell_0 + \ell_c < \ell_1 + \ell_2$$

identical

ANSWERS TO PROBLEMS - DOUBLE-ROCKER MECHANISM

6. Write the inequality that must be satisfied in figure 10-10 is to exist.

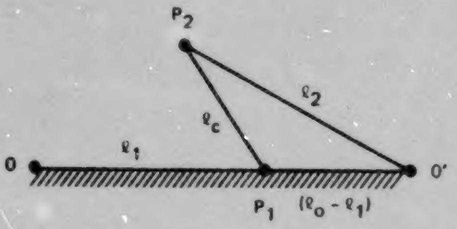


Fig. 10-10 Mechanism for Problem 6

$$\ell_2 < \ell_c + \ell_o - \ell_1$$

7. Show that your result in problem 6 is identifal to inequality 10-6 in the discussion.

Problem 6. $\ell_2 < \ell_c + \ell_o - \ell_1$

Eq. 10-6 (Corrected) $\ell_1 + \ell_2 < \ell_c + \ell_o$ Identical

or $\ell_2 < \ell_c + \ell_o - \ell_1$

LINKING MECHANISMS

ANSWERS TO PROBLEMS - FOUR-BAR SUMMARY

1. Write the twelve inequalities for the critical positions shown in figure 11-3.

a) $\ell_o + \ell_1 < \ell_c + \ell_2$
$\ell_2 < \ell_o + \ell_1 + \ell_c$
$\ell_c < \ell_2 + \ell_1 + \ell_o$

b) $\ell_o < \ell_2 + \ell_c - \ell_1$
$\ell_2 < \ell_o + \ell_c - \ell_1$
$\ell_c - \ell_1 < \ell_o + \ell_2$

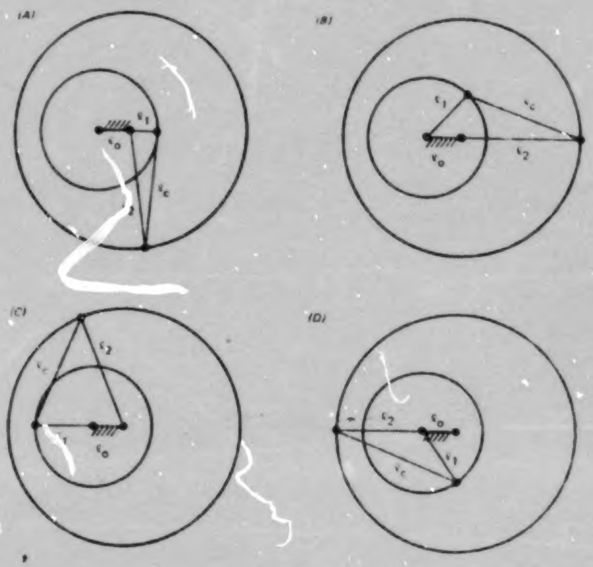
c) $\ell_o - \ell_1 < \ell_2 + \ell_c$
$\ell_2 < \ell_c + \ell_o - \ell_1$
$\ell_c < \ell_2 + \ell_o - \ell_1$

d) $\ell_o < \ell_2 + \ell_c + \ell_1$
$\ell_2 < \ell_o + \ell_c + \ell_1$
$\ell_c + \ell_1 < \ell_o + \ell_2$

2. Which of the inequalities in problem 1 simply state that one link must be shorter than the sum of the remaining links?

a-2 a-3 c-1 d-1 d-2

3. Draw sketches showing four critical positions of a type II four-bar mechanism.


(A)
ℓ_1
ℓ_o
ℓ_c
(B)
ℓ_1
ℓ_c
ℓ_o
ℓ_2
(C)
ℓ_2
ℓ_c
ℓ_1
ℓ_o
(D)
ℓ_2
ℓ_o
ℓ_1
ℓ_c

ANSWERS TO PROBLEMS - FOUR-BAR SUMMARY

4. Repeat problem 1 for the mechanism in problem 3.

a) $\ell_1 - \ell_o < \ell_2 + \ell_c$
$\ell_2 < \ell_c + \ell_1 - \ell_o$
$\ell_c < \ell_2 + \ell_1 - \ell_o$

b) $\ell_2 + \ell_o < \ell_1 + \ell_c$
$\ell_c < \ell_2 + \ell_o + \ell_1$
$\ell_1 < \ell_c + \ell_2 + \ell_o$

c) $\ell_c < \ell_1 + \ell_o + \ell_2$
$\ell_2 < \ell_c + \ell_1 + \ell_o$
$\ell_1 + \ell_o < \ell_c + \ell_2$

d) $\ell_2 - \ell_o < \ell_1 + \ell_c$
$\ell_c < \ell_1 + \ell_2 - \ell_o$
$\ell_1 < \ell_c + \ell_2 - \ell_o$

5. Repeat problem 2 for the mechanism in problem 3.

a-1 b-2 b-3 = a-1 c-1 = b-2 c-2

d-1 = c-2 Therefore, a-1, b-2, and c-2.

6. Which inequalities in problem 3 are the most useful in analyzing the mechanism?

$\ell_2 < \ell_c + \ell_1 - \ell_o$ $\ell_1 + \ell_o < \ell_c + \ell_2$

$\ell_c < \ell_2 + \ell_1 - \ell_o$

7. Using your inequalities from problem 6, show that ℓ_o must be the shortest link in a drag-link mechanism.

a-2 $\ell_o < \ell_c + \ell_1 - \ell_2$
a-3 $\ell_o < \ell_2 + \ell_1 - \ell_c$
c-3 $\ell_o < \ell_c + \ell_2 - \ell_1$

Adding a-2 and a-3
$$\begin{array}{l} \ell_o < \ell_c + \ell_1 - \ell_2 \\ \underline{\ell_o < -\ell_c + \ell_1 + \ell_2} \\ 2\ell_o < 2\ell_1 \\ \ell_o < \ell_1 \end{array}$$

Adding a-2 and c-3
$$\begin{array}{l} \ell_o < \ell_c + \ell_1 - \ell_2 \\ \underline{\ell_o < \ell_c - \ell_1 + \ell_2} \\ 2\ell_o < 2\ell_c \\ \ell_o < \ell_c \end{array}$$

Adding a-3 and c-3
$$\begin{array}{l} \ell_o < \ell_2 + \ell_1 - \ell_c \\ \underline{\ell_o < \ell_2 - \ell_1 + \ell_c} \\ 2\ell_o < 2\ell_2 \\ \ell_o < \ell_2 \end{array}$$

Therefore $\ell_o < \ell_1$
$\ell_o < \ell_c$ ℓ_o is the shortest link in a drag-link mechanism.
$\ell_o < \ell_2$

LINKING MECHANISM

UNIT VI

ANSWERS TO PROBLEMS - FOUR-BAR PROBLEM

1. What type of mechanism was used in the experiment?

   A double-rocker.

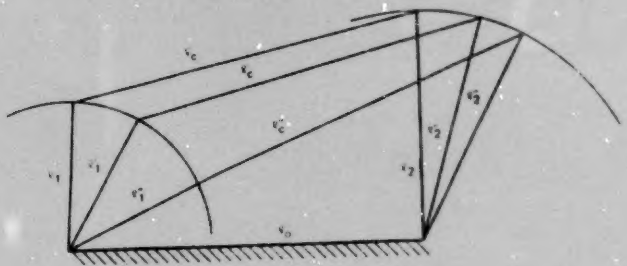
2. Give three different practical uses for the double-rocker mechanism.

   a. To increase displacement of mechanical oscillatory action.

   b. To decrease displacement of mechanical pullatory action.

   c. To change linear oscillatory action to nonlinear oscillatory action.

3. Show how equation 12.5 is obtained from the previous equation given in the discussion of this experiment.



$$\ell_c{}^2 = \ell_1{}^2 + \ell_o{}^2 + \ell_2{}^2 - 2\ell_1\ell_o\cos\phi - 2\ell_2\ell_1\cos\phi\cos\theta$$
$$- 2\ell_2\ell_1\sin\phi\sin\theta + 2\ell_2\ell_o\cos\theta$$

$$-2\;{}_2\ell_o\cos\theta + 2\ell_1\ell_o\cos\phi - \ell_o{}^2 - \ell_2{}^2 + \ell_c{}^2 - \ell_1{}^2 =$$
$$- 2\ell_2\ell_1\cos\phi\cos\theta - 2\ell_2\ell_1\sin\phi\sin\theta \text{ divided by } -2\ell_2\ell_1$$

$$\frac{\ell_o}{\ell_1}\cos\theta - \frac{\ell_o}{\ell_2}\cos\phi + \frac{\ell_o{}^2 + \ell_2{}^2 - \ell_c{}^2 + \ell_1{}^2}{2\ell_2\ell_1} = \cos\phi\cos\theta + \sin\phi\sin\theta$$

$$\frac{\ell_o}{\ell_1}\cos\theta - \frac{\ell_o}{\ell_2}\cos\phi + \frac{\ell_o{}^2 + \ell_2{}^2 - \ell_c{}^2 + \ell_1{}^2}{2\ell_2\ell_1} = \cos(\theta - \phi)$$

letting $\frac{\ell_o}{\ell_1} = K_1$

$\frac{\ell_o}{\ell_2} = K_2$

$\frac{\ell_o{}^2 + \ell_2{}^2 - \ell_c{}^2 + \ell_1{}^2}{2\ell_2\ell_1} = K_3$

we have equation 12.5.

ANSWERS TO PROBLEMS - FOUR-BAR PROBLEM

4. Using either graphical or analytical techniques, design a four-bar mechanism that will place the follower lever through 15 degrees as the driver lever goes through 26 degrees; then, as the driver lever goes another 33 degrees the follower moves through 11 degrees. In all cases the angular movement is in the clockwise direction.

Driver Lever	Follower
$\ell_1 \cong 1.3''$	ℓ_1 initial position is at 85°
$\ell_2 \cong 2.0''$	ℓ_2 initial position is at 90°
$\ell_c \cong 3.13''$	ℓ_1' initial position is at 59°
$\ell_o \cong 3.13''$	ℓ_2' initial position is at 75°
	ℓ_1'' initial position is at 26°
	ℓ_2'' initial position is at 64°

LINKING MECHANISMS

UNIT VI

ANSWERS TO PROBLEMS - SLIDER CRANK MECHANISMS

1. List at least one practical application of each of the four inversions of the slider-block mechanism shown in figure 13-1.

   a. Piston, crankshaft, and cylinder of a reciprocating gasoline engine.

   b. Flywheel punch

   c. Oil well pump

   d. Hand water pump

   Actually, any one answer could fit all four cases in some instances.

2. An in-line slider-crank mechanism has a crank length of 2 inches and a connecting rod length of 8 inches. The crank turns counterclockwise at 480 RPM. Find the following values when the crank is at 60 degrees (zero degrees is at the horizontal position when the slider is at TDC.)

   a. Slider displacement in inches.

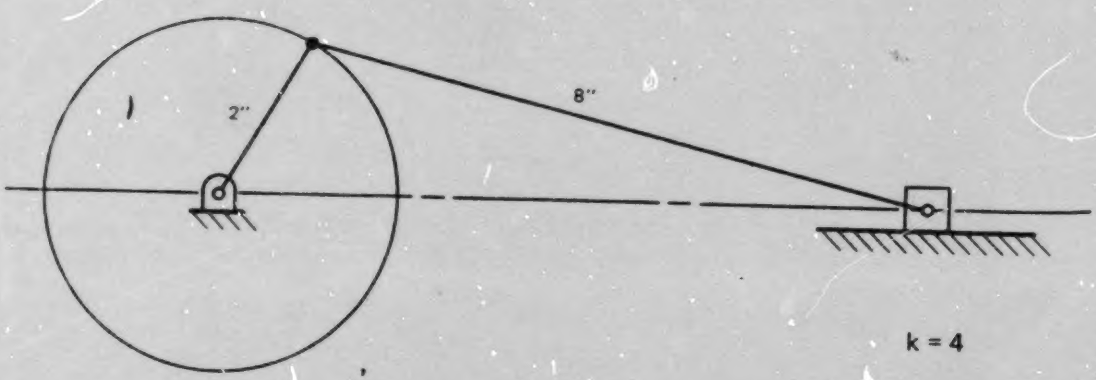
   b. Slider velocity in ft /sec.

   c. Slider acceleration in ft/sec^2.

   d. Connecting rod angular velocity in rad/sec.

   e. Connecting rod angular acceleration in rad/sec^2.

   f. The crank angle giving maximum slider velocity in radians and in degrees.



ANSWERS TO PROBLEMS - SLIDER CRANK MECHANISMS

a. $d \approx \ell_1 (1 - \cos\theta) + \frac{\ell_1{}^2}{2\ell_c} \sin^2\theta)$

$d = 2''(1 - \cos 60^\circ) + \frac{2''^2}{16''} \sin^2 60^\circ)$

$d = 2'' (1-0.5) + 0.25 (0.866)^2$

$d = 1 + (0.25)(0.75) = 1 + 0.188$

$d \simeq 1.19''$ from TDC

b. $V_p = \ell_1 \omega(\sin\theta + \frac{\sin 2\theta}{2K})$

$V_p = 2(50 \text{ rad/sec}) (\sin 60^\circ + \frac{\sin 120^\circ}{8})$

$V_p = 100 (0.866 + \frac{0.866}{8})$

$V_p = 97.4$ in/sec

c. $a_p = \ell_1\omega^2 (\cos\theta + \frac{\cos 2\theta}{k})$

$a_p = 2 (50) (0.5 + \frac{0.5}{4})$

$a_p = 5000 (0.375) = 1870 \text{ in/sec}^2$

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ANSWERS TO PROBLEMS - SLIDER CRANK MECHANISMS

d. $\omega_{P_1P_2} = 1\left[\frac{\omega \cos \theta}{(k^2 - \sin^2 \theta)^{1/2}}\right]$

$$\omega P_1P_2 = \frac{50(0.5)}{(16 - .75)^{1/2}} = \frac{25}{3.9}$$

$$\omega P_1P_2 = 0.4 \text{ rad/sec}$$

e. $\alpha_{P_1P_2} = \frac{\omega^2(k^2 - 1) \sin \theta}{(k^2 - \sin^2 \theta)^{2/3}}$

$$\alpha_{P_1P_2} = \frac{(50)^2 (16-1)\ 0.866}{(16-0.75)^{2/3}}$$

$$\alpha P_1P_2 = \frac{(2500)\ (15)\ (0.866)}{13.2}$$

$$\alpha P_1P_2 = 2400 \text{ rad/sec}^2$$

f. $\theta = 90^o = 1.57$ rad

or $\theta = 270^o = 4.71$ rad

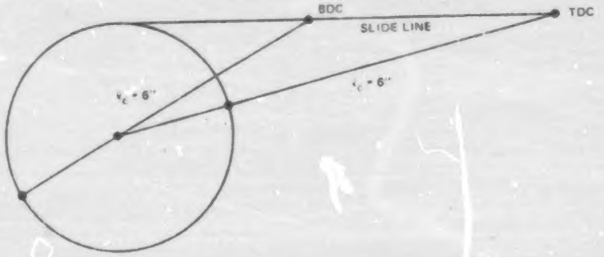
3. A sliding-block mechanism has a 2 inch crank and a 6 inch connecting rod. The stroke line of the slider is horizontal and located 2 inches above the center of the crank. Make a neat, scale drawing of this mechanism and determine the length of the stroke in inches. Then, assume the crank rotates at a constant speed of 120 RPM, and determine the time in seconds for the forward and the return stroke. The crank is rotating in a clockwise direction.

Stroke = 4.25"
120 rev/min
Forward stroke takes 1/2 rev.

$\frac{1}{120 \text{ rev/min}}$ = 0.00836 min/rev

$\frac{1}{2}$ (0.00836) = 0.00417 min for stroke

0.00417 min for either stroke



LINKING MECHANISMS

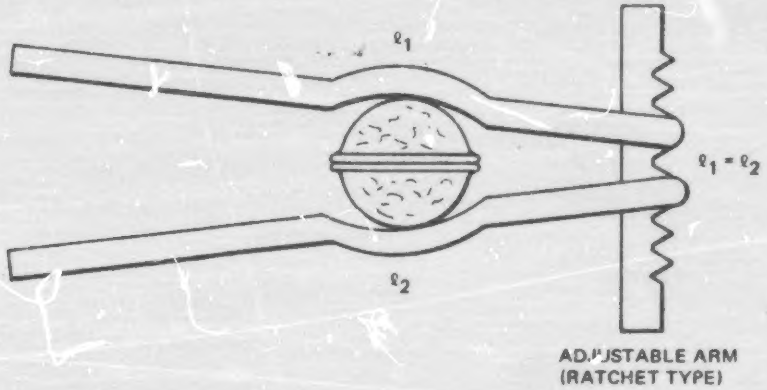
UNIT VI

ANSWERS TO PROBLEMS - TOGGLE LINKAGES

1. A certain stone crushing machine employs equal length arms in a toggle mechanism. If the toggle angle never exceeds 2.0 degrees, what input force is required to produce a minimum load force of 1,000,000 pounds?

$$\theta = 2^o$$
$$f = 2F \tan \theta$$
$$f = (2)\ (1 \times 10^6)\ (\tan 2^o)$$
$$f = (2)\ (1 \times 10^6)\ (.035) = 7 \times 10^4 \text{ pounds}$$

2. Make a sketch showing how a nutcracker using a toggle mechanism can be adjusted to accommodate nuts of various sizes.



3. A pair of toggle pliers requires a force of 22 pounds to hold the toggle angle at 3 degrees. If the toggle links are of equal length, what is the load force?

$$F = \frac{f}{2 \tan \theta} = \frac{22}{2\ (.052)} = \frac{22}{.104} = 21.1 \text{ lbs.}$$

4. A certain toggle mechanism has unequal links of $\ell_1 = 8$ inches and $\ell_2 = 5$ inches. What is the ratio f/F at a toggle angle of: 1.0 degree? 5.0 degrees? 30 degrees?

ANSWERS TO PROBLEMS - TOGGLE LINKAGES

4.

$$\frac{f}{F} = \frac{\ell_1 + \ell_2}{\ell_1} \tan \qquad \ell_1 = 8''$$

$$\ell_2 = 5''$$

$$1^o: \frac{f}{F} = \frac{13''}{8} (0.018) \frac{.234}{8} = \frac{0.0290}{1}$$

$$5^o: \frac{f}{F} = \frac{13}{8} (0.088) = \frac{1.44}{8} = \frac{0.143}{1}$$

$$30^o: \frac{f}{F} = \frac{13}{8} (0.577) = \frac{7.5}{8} = \frac{0.937}{1}$$

5. Work out problem 4 using both equations 29.4 and 29.5. What, if any, difference do you observe?

There should be no difference because:

$$\frac{f}{F} = \frac{\ell_1 + \ell_2}{\ell_1} (\tan \theta) = 1 + \frac{\ell_2}{\ell_1} (\tan \theta)$$

6. List several practical applications of a toggle mechanism.

Several mechanical tools such as pliers, wire cutters, and bolt cutters.

LINKING MECHANISMS

UNIT VI

ANSWERS TO PROBLEMS - TOGGLE LATCHING

1. A pair of eoggle latch pliers has equal length toggle links and a toggle angle of 2 degrees. What is the unlatching force if the load effective at the toggle end is 300 pounds?

$$\frac{f}{F} = 2 \tan \theta$$

$$f = 2F \tan \theta = 2\ (300\ \text{lbs.})\ (.035) = 210\ \text{lbs.}$$

2. What type of four-bar mechanism is represented by the pliers in figure 30-3? Assume ℓ_1 = 1 3/8 inches, ℓ_2 = 1 3/8 inches, ℓ_3 = 1 inch, and ℓ_o = 2 1/2 inches.

Simple toggle mechanism (latching type, class #2).

3. A mechanism like figure 30-1 is used to lock an automobile life in its "up" position. If the links are ℓ_1 = 4 feet, ℓ_2 = 3 1/2 feet, ℓ_3 = 2 1/2 feet, and ℓ_4 = 6 inches, and the effective load is 4500 pounds, what would be the unlatching force for a toggle angle of 3.5 degrees?

$$f = F \frac{(\ell_3 + \ell_4)\ (\ell_1 + \ell_2)}{\ell_1\ \ell_3} \tan$$

$\ell_1 = 4'$ $\quad \ell_3 = 2.5'$ $\quad \theta = 3.5$

$\ell_2 = 3.5$ $\quad \ell_4 = 0.5'$

$$f = (4500) \frac{(3')\ (7.5')}{10'} (0.061)$$

F = 4500 lbs.

$$f = \frac{101.000}{10}\ (0.061) = 610\ \text{lbs.}$$

4. What would be the force on the toggle stop in problem 3 if S = 2 1/2 feet? Assume the mechanism to be fully latched when = 3.5 degrees.

$$f' = f \frac{\ell_1}{S}$$

$$f' = (610\ \text{lbs.}) \frac{(4')}{(2.5')} = (1.6)\ (610) = 960\ \text{lbs.}$$

ANSWERS TO PROBLEMS - TOGGLE LATCHING

5. List three practical applications of a toggle latch mechanism.

Mechanical tools such as vice-grips, automobile jack, etc.

LINKING MECHANISMS

UNIT VI

TEST ANSWERS

1. a. 20
   b. 24
   c. 23
   d. 22
   e. 19
   f. 18
   g. 17
   h. 15
   i. 2
   j. 10
   k. 13
   l. 9 or 5
   m. 4
   n. 12
   o. 5 or 9
   p. 7
   q. 8
   r. 11
   s. 3
   t. 25
   u. 16
   v. 21
   w. 1
   x. 6
   y. 14

2. What are the characteristics of a mechanism as opposed to a structure?

   A structure is a system in which the members cannot move in a predictable relative motion. The only motion that can occur is if one or more of the links is deformed. A mechanism is when one link of a linkage is fixed and the other links have specified motion.

3. What is the test for a four-bar mechanism? $\ell_o + \ell_1 + \ell_2 > \ell_c$

4. Verify that a mechanism with lengths $\ell_1 = 0.5"$, $\ell_2 = 2"$, $\ell_c = 6"$, $\ell_o = 5.55"$ is a crank-rocker mechanism.

   $\ell_o < \ell_c \quad \ell_2 \quad \ell_1$

   $5.55 < 6 + 2 - 0.5 -$
   $5.55" < 7.5"$

5. List and discuss three practical applications for the drag-link mechanism.

   One application of the drag-link is in the quick-return mechanism. the reason for using the quick-return mechanism is that some link has a working stroke, that is, the stroke during which the objective of the mechanism, such as cutting metal or form pressing, is being accomplished. On the return stroke of the mechanism, nothing is accomplished except that the mechanism is returned to the beginning of its working stroke. By speeding up the return stroke, the output of the machine can be increased. -- Another application is the steering mechanism in automobiles and direct to oscillating motion conversion.

TEST ANSWERS

6. State criteria necessary for a mechanism to work as a double-rocker.

$\ell_c < \ell_o$

$\ell_2 < \ell_1$

$\ell_o < \ell_2 + \ell_1 - \ell_c$

$\ell_o - \ell_2 < \ell_c + \ell_1$

7. Consider a mechanism having link lengths of:

$\ell_1 = 1$ in $\qquad \ell_2 = 2$ in

$\ell_o = 2.5$ in $\qquad \ell_c = 2$ in

A. $\ell_1 + \ell_o + \ell_2 > \ell_c$

$1 + 2.5 + 2 > 2$

$5.5 > 2$. It is possible to build.

B. ℓ_1 is the shortest

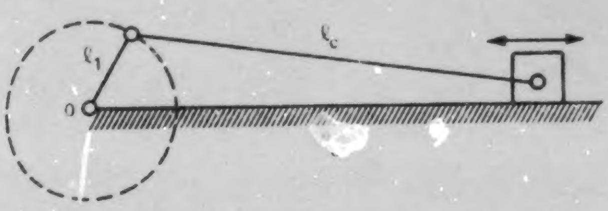
$\ell_c - \ell_2 + \ell_1 < \ell_o < \ell_c + \ell_2 - \ell_1$

$2 - 2 + 1 < 2.5 < 2+2 - 1$

$1 < 2.5 < 3$ Therefore the mechanism is a crank-rocker.

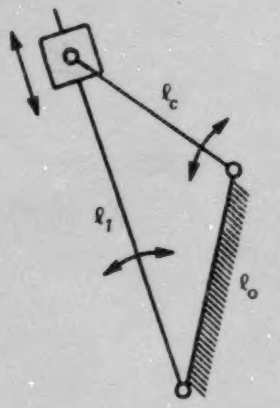
8. Name a practical application for each type of slide-crank mechanism shown.

a. Piston and crank of reciprocating engine.

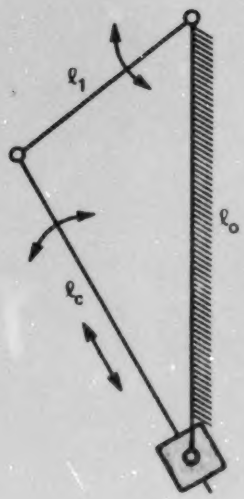


TEST ANSWERS

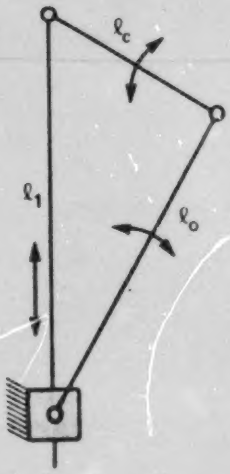
b. Flywheel punch


ℓ_c
ℓ_1
ℓ_o

c. Oil well pump


ℓ_1
ℓ_o
ℓ_c

d. handwater pump


ℓ_c
ℓ_1
ℓ_o

TEST ANSWERS

9. List three practical applications of a toggle mechanism.

   Pliers, nutcracker, wire cutter, bolt cutter

10. Name two practical applications of a toggle latch mechanism.

    vice grips, automobile jack

MECHANICAL DEVICES

UNIT VII

CAMS

CAMS

UNIT VII

OBJECTIVE

After completing this unit, the student should be able to construct mechanisms that will translate rotary motion into transtational or oscillatory motion to perform required functions utilizing cams in various configurations. This knowledge will be shown by completing an assignment sheet, lab procedures, problems and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with cams to their definitions.
2. Sketch the three common forms of cam motion.
3. Sketch the displacement graph for a disk cam motion.
4. Sketch a timing chart for a system of cams.
5. Discuss the characteristic of a geneva mechanism.
6. Calculate quantities of a geneva mechanism.
7. Demonstrate the ability to
    a. Construct a mechanism that will translate rotary motion to translational motion.
    b. Construct a mechanism that translates rotary motion to reciprocating or oscillating motion.
    c. Construct a mechanism that provides multiple timing.
    d. Construct a mechanism that provides intermittent motion with constant velocity.
    e. Construct a mechanism that produces a constant output load with a varying input load.

CAMS

UNIT VII

SUGGESTED ACTIVITIES

I. Instructor

- A. Provide students with objective sheet.
- B. Provide students with procedure sheet and Drives text.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss labs and problems from Drives.
- F. Demonstrate forms of cam motion.
- G. Demonstrate an application of a geneva mechanisms.
- H. Assist students in constructive cam type mechanism.
- I. Assist students in lab calculations.
- J. Give test.

II. Student

- A. Read objective sheet.
- B. Complete procedure sheets.
- C. Take test.

CAMS

UNIT VII

INSTRUCTIONAL MATERIAL

I. Included in this unit:

A. Objective sheet.

B. Procedure sheet.

C. Test.

D. Answers to assignment sheets.

E. Answers to test.

II. References

A. Tinnell, Richard W., DRIVES, Waco, Texas, Center for Occupational Research and Development, 1977.

B. Tinnell, Watts, Yeagan, Teel, LINKAGES, Waco, Texas, Center for Occupational Research and Development, 1977.

C. Teel, Larry, MACHINES, Waco, Texas, Center for Occupational Research and Development, 1977.

III. Additional Material

A. MECHANICAL DEVICES AND SYSTEMS, Waco, Texas, Center for Occupational Research and Development,1981.

CAMS

UNIT VII

PROCEDURE SHEET

_____1. Complete — Assignment Sheet #1 - using Experiments 15, 16, 18 and 21, "Linkages", Pages 103-118, 130-139 and 150-153.

_____2. Study — Translational Cams, "Linkages", Pages 103-109.

_____3. Do — Lab Procedures, Pages 106-108.

_____4. Stop — Have your instructor review your results. If necessary redo Step 3.

_____5. Complete — Problems, "Linkages", Page 109.

_____6. Stop — Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 7. Otherwise repeat Steps 2, 5 and 6.

_____7. Write — An informal lab report for Translational Cams. Use the informal format described on Page 207, "Drives".

_____8. Study — Disk Cams, "Linkages", Pages 110-118.

_____9. Do — Lab Procedures, Pages 115-118.

____10. Stop — Have your instructor review your results. If necessary redo Step 9.

____11. Complete — Problems, "Linkages", Page 118.

____12. Stop — Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 13. Otherwise repeat Steps 8, 11 and 12.

____13. Write — An informal lab report for Disk Cams. Use the informal format described on Page 207, "Drives".

____14. Study — Multiple Cam Timing, "Linkages", Pages 130-139.

____15. Do — Lab Procedures, "Linkages", Pages 135-138.

____16. Stop — Have your instructor review your results. If necessary redo Step 15.

____17. Complete — Problems, "Linkages", Page 139.

PROCEDURE SHEET

____18. Stop — Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 19. Otherwise repeat Steps 14, 17 and 18.

____19. Write — An informal lab report for Multiple Cam Timing. Use the informal format described on Page 207, "Drives".

____20. Study — Loading Geneva Mechanisms, "Linkages". Pages 150-153.

____21. Do — Lab Procedures, "Linkages", Pages 152-153.

____22. Stop — Have your instructor review your results. If necessary redo Step 21.

____23. Complete — Problems, "Linkages", Page 153.

____24. Stop — Have your instructor evaluate your problems. If your instructor is satisfied with your performance continue to Step 25. Otherwise repeat Steps 20, 23 and 24.

____25. Write — An informal lab report for Loading Geneva Mechanisms, Use the informal format described on Page 207, "Drives".

____26. Turn-In — All lab reports before continuing.

____27. Review — Chapters 15, 16, 18 and 21, "Linkages".

____28. Complete — Unit Test - Cams

____29. Stop — Have your instructor evaluate the Unit Test - Cams. If your instructor is satisfied with your performance, CONGRATULATIONS! You have completed this course. Otherwise review the areas suggested by your instructor and repeat Steps 28 and 29.

CAMS

UNIT VII

ASSIGNMENT SHEET #1 - TERMS AND DEFINITIONS ASSOCIATED TO CAMS

1. Translational Cam -
2. Follower -
3. Frame -
4. Cam -
5. Cam Follower -
6. Cam Zero Position -
7. Simple Harmonic Motion -
8. Prime Circle -
9. Normal Force -
10. Pressure Angle -
11. Multilobe Cam -
12. Dwell Time -
13. Dwell Angle -
14. Geneva Mechanism -

CAMS

UNIT VII

TEST

NAME____SCORE:_________

1. Match terms associated with cams to their definitions. Mark the correct number in the blank.

_____a. A type of cam which has a profile that produces more than two follower positions during one revolution.

_____b. The angle on the cam profile as the cam changes state.

_____c. The position in which the cam follower is closest to the center of the cam.

_____d. The element which slides or rolls over the cam profile and transmits rotary to linear motion.

_____e. The driving link which imparts information to the follower as to magnitude and motion.

_____f. A device used to translate rotary motion into reciprocating or oscillating motion.

_____g. A circle with a radius from the cam center to the point of minimum displacement of the cam roller.

_____h. The resultant force between the cam and the cam roller which is normal or perpendicular to the outer edge surface of the cam.

_____i. The time during which two or more synchronized cams have the same state.

_____j. A device that consists of two parts, a driver and a star wheel. The operation of this mechanism produces intermittent motion.

1. Follower
2. Cam
3. Cam Zero Position
4. Prime Circle
5. Pressure Angle
6. Dwell Time
7. Geneva Mechanism
8. Translational Cam
9. Frame
10. Cam Follower
11. Simple Harmonic Motion
12. Normal Force
13. Multilobe Cam
14. Dwell Angle

TEST

_____k. The angle between the follower centerline and the normal force line.

_____l. That motion which closely approximates sinusoidal motion.

_____m. The device which is in contact with the cam outer edge, and which produces a linear motion as a result of the rotary motion of the cam.

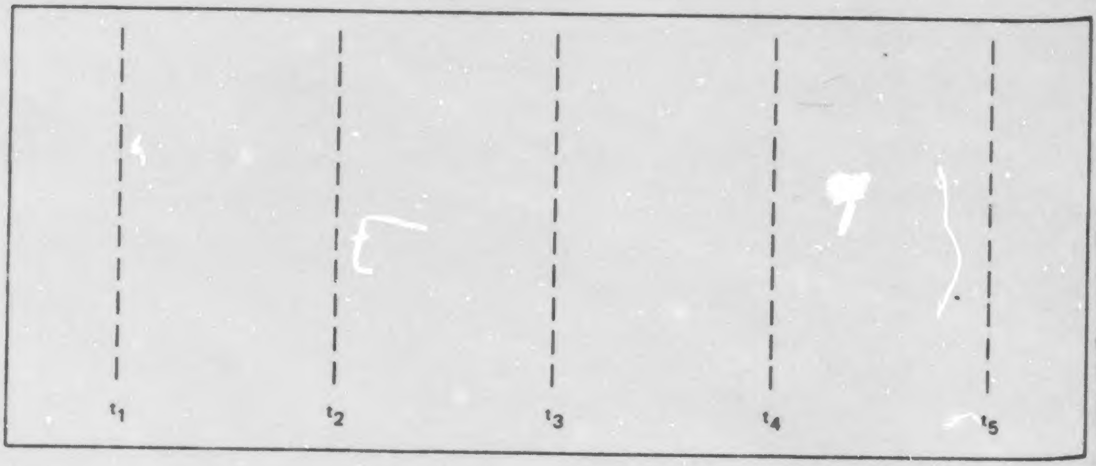
_____n. That link which is stationary and provides support for the cam and follower actions.

2. Sketch examples of uniform, harmonic, and uniformly accelerated and decelerated cam motion using a set of axes.

TEST

3. Draw the displacement graph for a medium speed cam whose follower must rise one inch during the first 60 degrees of camshaft rotation, dwell for the next 30 degrees, return to the initial point during the next 60 degrees, and dwell for the remaining 210 degrees.

4. Sketch, using the timing chart in figure 1, how three cams could be used to turn on a green light for 1 /2 of a cam revolution; then turn on an amber lamp for 1 /6 of a revolution; then turn on a red lamp for 1 /3 of a revoluation.



TEST

5. For a Geneva Mechanism:

   a. How does the ratio of input and output velocity vary with the number of slots of a geneva wheel (averaged over long time periods)?

   b. What are some of the possible problems that one might encounter in driving geneva wheel mechanisms at high RPMs?

   c. What is the major advantage of the internal type as compared to the external type geneva mechanism?

TEST

6. Calculate the length of the driven crank ℓ_2 at 30^0 for an eight slot geneva wheel.

7. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, CONGRATULATIONS! you have completed this Section. Continue on to the next Section. If additional study is necessary ask your instructor about study requirements and possible retesting.

CAMS

UNIT VII

ANSWERS TO ASSIGNMENT SHEET #1

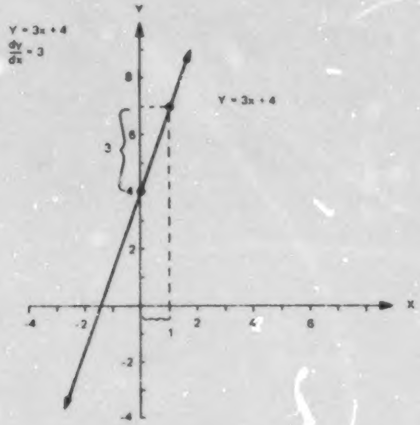
1. Translational Cam - The driving link which imparts information to the follower as to magnitude and motion.
2. Follower - The element which slides or rolls over the cam profile and transmits rotary to linear motion.
3. Frame - That link which is stationary and provides support for the cam and follower actions.
4. Cam - A device used to translate rotary motion into reciprocating or oscillating motion.
5. Cam Follower - The device which is in contact with the cam outer edge, and which produces a linear motion as a result of the rotary motion of the cam.
6. Cam Zero Position - The position in which the cam follower is closest to the center of the cam.
7. Simple Harmonic Motion - That motion which closely approximates sinusoidal motion.
8. Prime Circle - A circle with a radius from the cam center to the point of minimum displacement of the cam roller.
9. Normal Force - The resultant force between the cam and the cam roller which is normal or perpendicular to the outer edge surface of the cam.
10. Pressure Angle - The angle between the follower centerline and the normal force line.
11. Multilobe Cam - A type of cam which has a profile that produces more than two follower positions during one revolution.
12. Dwell Time - The time during which two or more synchronized cams have the same state.
13. Dwell Angle - The angle on the cam profile as the cam changes state.
14. Geneva Mechanism - A device that consists of two parts, a driver and a star wheel. The operation of this mechanism produces intermittent motion.

CAMS

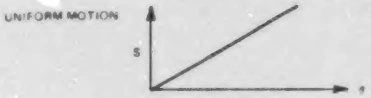
UNIT VII

ANSWERS TO PROBLEMS - TRANSLATIONAL CAMS

1. If the mathematical equation for the motion of a transverse cam if Y = 3x + 4, how many units will the cam follower move vertically for each unit of motion of the horizontal cam? (Hint: Use the first derivative of the equation, or make a quick plot of its graph.)

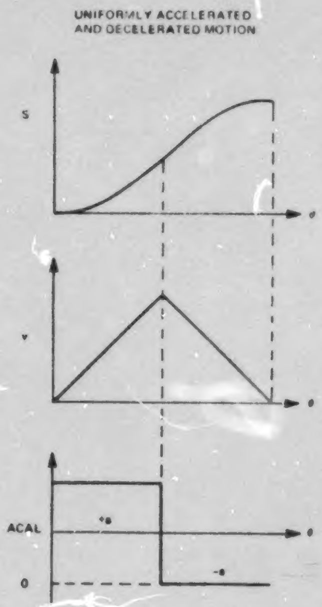


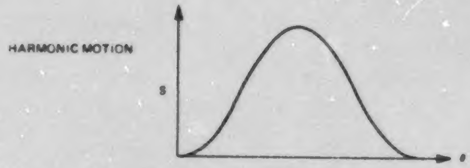
2. In the discussion, three common forms of cam motion are mentioned: uniform, harmonic, and uniformly accelerated and decelerated motions. Draw a sketch of each type of motion. If necessary look this up in a mechanical engineer's handbook.



THE SLOPE OF THE UNIFORM MOTION CAN BE ZERO OR A CONSTANT VALUE, EITHER ONE OF WHICH IMPLIES ZERO ACCELERATION.

ANSWERS TO PROBLEMS - TRANSLATIONAL CAMS





3. What is meant by the expression "cam-follower pressure angle"? What is the maximum pressure angle that you would expect to be used in practical cam designs? Was this point illustrated in this experiment? Explain and discuss.

The cam-follower pressure angle is that angle between the normal force (acting perpendicularly from the cam profile) and the follower's centerline. The maximum pressure angle is usually 30°. By using the formula $F_x - F_n \sin \theta$ it is easily seen that the lateral force could equal one-half of the normal force. This would cause excess wear and will lead to roller or cam failure.

The concept of pressure angles is easily seen when measuring the displacement-degree change of lines A, B, and C. Since the speed of travel was very slow, the effect of pressure angles was zero.

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ANSWERS TO PROBLEMS - TRANSLATIONAL CAMS

4. The graph used in this experiment is known as a displacement graph. By what other name is the ratio dy/dx (change in displacement with respect to time) known? Velocity

5. Assume that the cam you used moved from the leading corner to the trailing corner in two seconds at a uniform velocity. What is the cam-follower's velocity vertically when the cam has moved 2 inches? Express your answer in both mm/sec and in ft/sec.

$$\text{Cam Velocity} = \frac{\text{Distance}}{\text{Time}} = \frac{4.25''}{2\text{ sec}} = 2.125\,\frac{\text{inches}}{\text{sec}}$$

$$\text{The follower's velocity} = \frac{\text{follower's displacement}}{\text{time}}$$

$$\begin{aligned}\text{Follower's displacement } y &= 2r\sin\frac{\theta}{2}\\ &= 2\,(2\text{ inches})\sin\frac{11^\circ}{2}\\ &= 4\text{ inches }(.096)\\ &= 0.384\text{ inches}\end{aligned}$$

The time for cam to be at 2'' =

$$\frac{2\text{ inches}}{T} = \frac{2.125\text{ inches}}{1\text{ sec.}}$$

$$2\text{ inch-sec} = T\,(2.125\text{ inches})$$

$$T = \frac{2\,\cancel{\text{inch}}\text{-sec}}{2.125\,\cancel{\text{inches}}}$$

$$T = 0.94\text{ seconds}$$

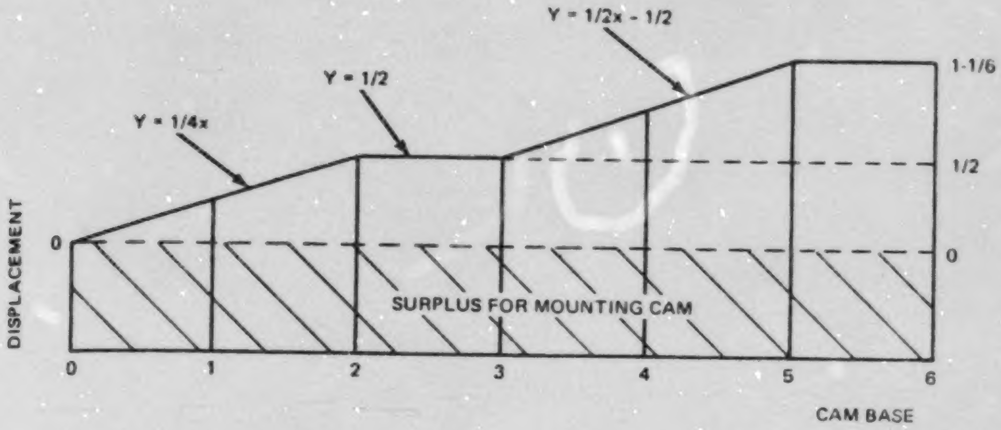
$$\text{Follower's velocity} = \frac{0.384\text{ inches}}{0.94\text{ sec}} = 0.408\text{ inches/sec}$$

$$0.408\,\frac{\cancel{\text{inches}}}{\text{sec}} \cdot \frac{1\text{ Ft}}{12\,\cancel{\text{inches}}} = 0.034\text{ ft/sec}$$

$$0.408\,\frac{\cancel{\text{inches}}}{\text{sec}} \cdot \frac{2.54\,\cancel{\text{cm}}}{1\,\cancel{\text{inch}}} \cdot \frac{10\text{ mm}}{1\,\cancel{\text{cm}}} = 10.4\,\frac{\text{mm}}{\text{sec}}$$

6. Lay out a 6-inch cam profile that will satisfy the following conditional equations:

$y = 1/4x$	$0 < x < 2$
$y = 1/2$	$2 < x < 3$
$y = 1/3x - 1/2$	$3 < x < 5$
$y = 1\ 1/6$	$5 < x < 6$


Y = 1/2x - 1/2
Y = 1/2
Y = 1/4x
1-1/6
1/2
0
0
DISPLACEMENT
SURPLUS FOR MOUNTING CAM
0
1
2
3
4
5
6
CAM BASE

$y = 1/4x$	$0 < x < 2$	Slope = 1/4	$b = 0$
$y = 1/2$	$2 < x < 3$	Slope = 0	$b = 1/2$
$y = 1/3x - 1/2$	$3 < x < 5$	Slope = 1/3	$b = -1/2$
$y = 1\ 1/6$	$5 < x < 6$	Slope = 0	$b = 1\ 1/6$

7. Describe in your own words the cam follower motion that would result from the cam profile in problem 6.

From the leading corner of the cam the follower would travel up a 1/4 slope for a horizontal distance of 2 inches. Then it would move horizontally for one inch and start up an incline with a slope of 1 /3. After traveling for another two inches, the follower would move horizontally for one inch at a vertical height of 1 1 /6 inches.

CAMS

UNIT VII

ANSWERS TO PROBLEMS - DISK CAMS

1. Write the mathematical expression (equation) for figure 16-3. Express this equation both as $y = f(\sin \theta)$ and $y = f(\cos = \theta)$.

   $y = f(\sin \theta)$

   θ = Angle of rotation with respect to vertical axis.

   radius = r

   $\sin \theta = (180^o - \theta)$

   Therefore, $y = r(\sin 180^o - \theta) - r$ = distance from zero.

   $y = 4(\cos \theta) - r$ = distance from zero.

2. If the cam whose follower motion is represented by figure 16-3 rotates at a speed of 1800 RPM, what is the velocity of the follower at the 30 degree position, the 90 degree position, the 180 degree position, and the 360 degree position?

   30^o: $r = .125 + .625 = .750"$

   ω = 1800 RPM

   $v = (.750)(1800 \text{ RPM}) = 1350$ in-min

   90^o: $r = .625 + .625 = 1.250"$

   $v = (1.25")(1800 \text{ RPM}) = 2250$ in-min

   180^o: $r = 2.25 + .625 = 2.875"$

   $v = (2.875")(1800 \text{ RPM}) = 5180$ in-min

   360^o: $r = .625"$

   $v = (.625)(1800 \text{ RPM}) = 1130$ in-min

3. With the cam used in this experiment, assume that the spring tension is 3 pounds when the pressure angle is a maximum. Compute the normal force and the lateral force felt by the roller.

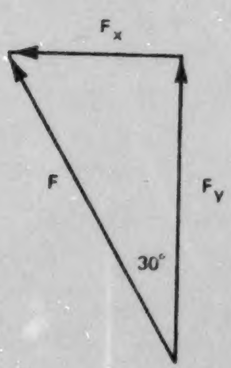
   $F_x = F \sin \phi$

   $\phi = 30^o$

   $F_y = 3$ lbs

   $F = \dfrac{F_y}{\cos 30^o}$

ANSWERS TO PROBLEMS - DISK CAMS



$$F = \frac{3\ \text{lb.}}{.866} = 3.46\ \text{lbs.}$$

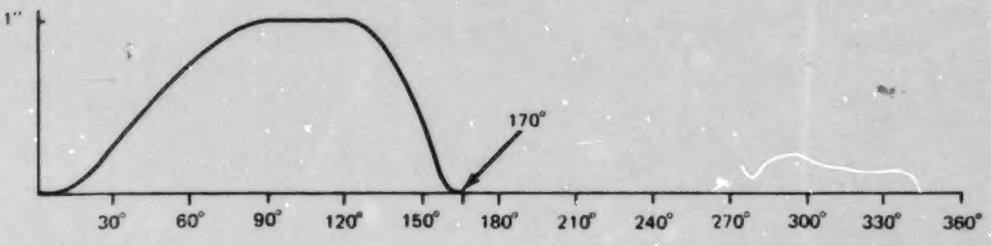
$$F_x = F \sin \phi$$

$$F_x = (3.46\ \text{lbs.})\ (.500) = 1.730\ \text{lbs.}$$

4. For a given cam it is found that the maximum pressure angle is 30 degrees. It is decided to rebuild the cam using a minimum radius twice the original. Is the new pressure angle increased or decreased? Explain.

   The pressure angle will decrease because the surface of the cam is not so steep. This means the normal force will be at lesser angle with respect to the tangent line. Refer to figure 16-6.

5. Draw the displacement graph for a medium speed cam whose follower must rise one inch during the first 90 degrees of camshaft rotation, dwell for the next 30 degrees, return to the initial point during the next 50 degrees, and dwell for the remaining 190 degrees.



CAMS

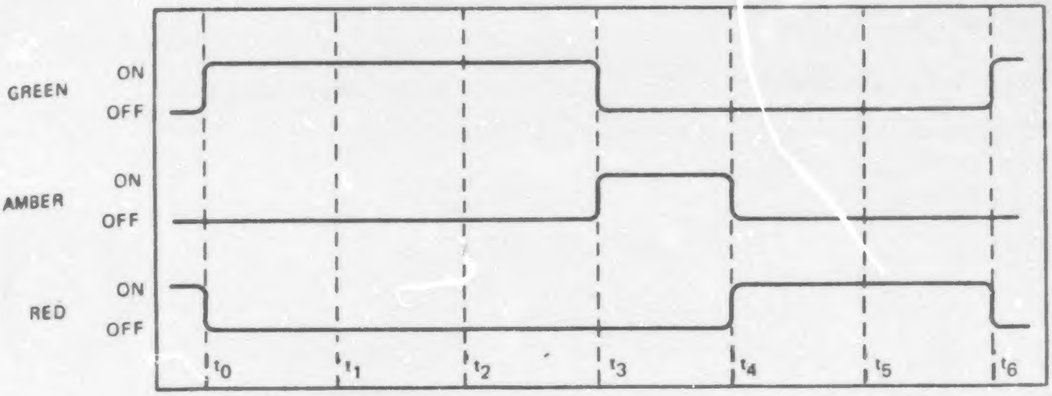
UNIT VII

ANSWERS TO PROBLEMS - MULTIPLE CAM TIMING

1. Make a sketch showing how three cams could be used to produce the same results as those observed in the experiment.

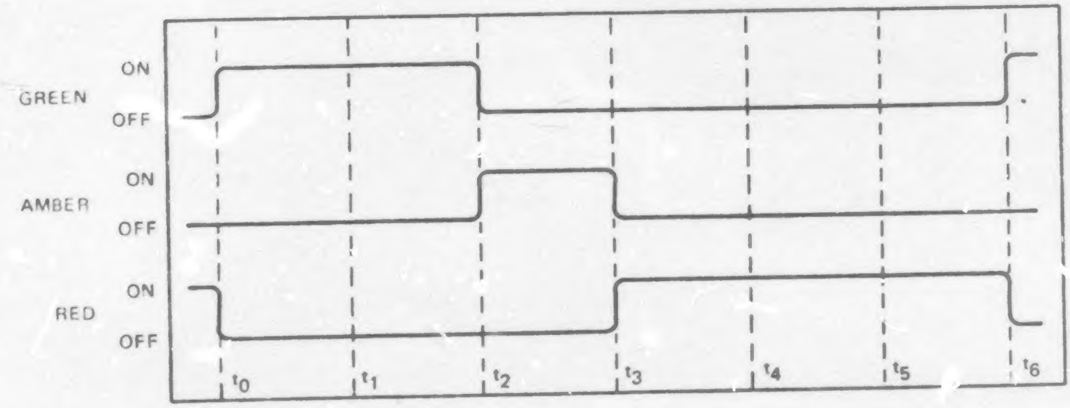
First Case

Green – 1/2 Rev.
Amber – 1/6 Rev.
Red – 1/3 Rev.



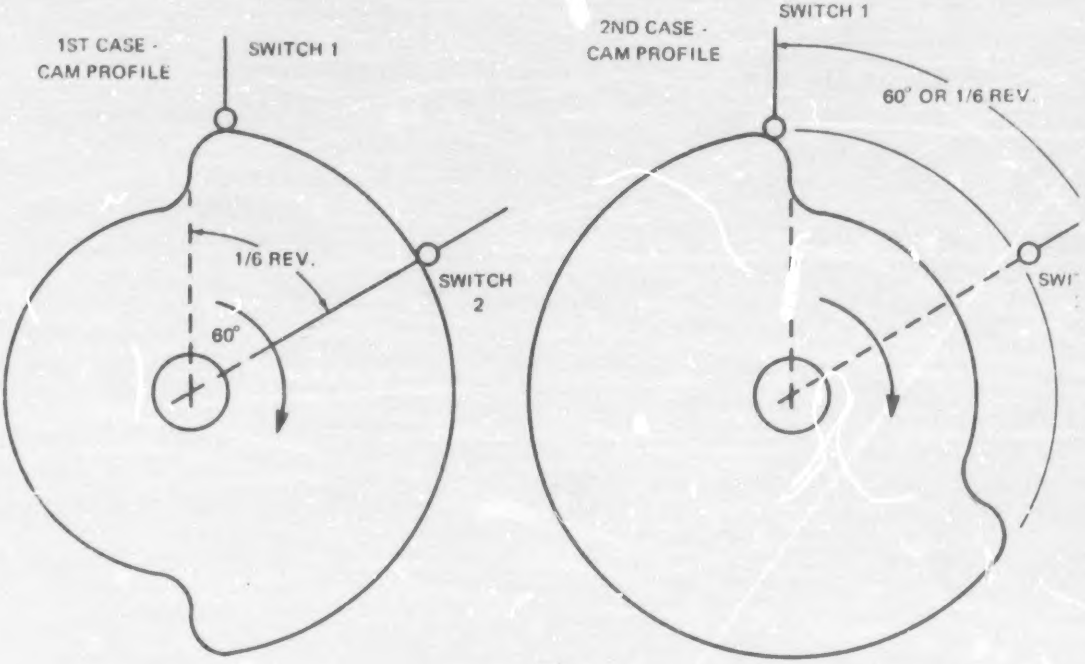
Second Case

Green – 1/3 Rev.
Amber – 1/6 Rev.
Red – 1/2 Rev.



ANSWERS TO PROBLEMS - MULTIPLE CAM TIMING

2. Repeat problem 1 using only one cam and two followers.


1ST CASE -
CAM PROFILE
SWITCH 1
1/6 REV.
60°
SWITCH
2
2ND CASE -
CAM PROFILE
SWITCH 1
60° OR 1/6 REV.
SWI

3. If a cam has a dwell angle of 180° and is rotating at 35 RPM, how long (in seconds) is the follower on the cam?

$$X = 180^\circ \frac{1}{(35\,\frac{\cancel{rev}}{\cancel{min}})\,(\frac{\cancel{min}}{60\,\cancel{sec}})\,(\frac{\cancel{2\pi\,rad}}{\cancel{rev}})\,(\frac{\cancel{360^\circ}\ 6}{\cancel{2\pi\,rad}})}$$

$$= 180^\circ \frac{1}{\frac{(35)\ 6^\circ}{sec}}$$

$$= 180^\circ\,(0.00476\ \tfrac{sec}{\circ})$$

$$X = 0.856\ sec.$$

4. What would be the result if the dwell angle in problem 3 were 110°?

$$X = 110^\circ \frac{1}{(35\,\frac{\cancel{rev}}{\cancel{min}})\,(\frac{\cancel{min}}{\cancel{60}\,sec})\,(\frac{\cancel{2\pi\,rad}}{\cancel{rev}})\,(\frac{\cancel{360^\circ}\ 6}{\cancel{2\pi\,rad}})} = 110^\circ \frac{1}{\frac{(35)\ 6^\circ}{sec}}$$

$$= 110^\circ\,(0.00476\ \tfrac{sec}{\circ})$$

$$X = 0.524\ sec.$$

ANSWERS TO PROBLEMS - MULTIPLE CAM TIMING

5. How long is the follower in problem 4 off the cam?

$$X = (360^\circ - 110^\circ)\,(0.00476\ \tfrac{\text{sec}}{\circ})$$

$$= 250^\circ\,(0.00476\ \tfrac{\text{sec}}{\circ})$$

$$X = 1.19\ \text{sec.}$$

6. The cam in problem 4 is directly coupled to a second cam with a dwell angle of 80°. If the lobes are displaced from each other by 45°, what would be the overlap time? (Assume that the 110° cam has its follower come on the lobe 45° before the other one comes up on its lobe.)

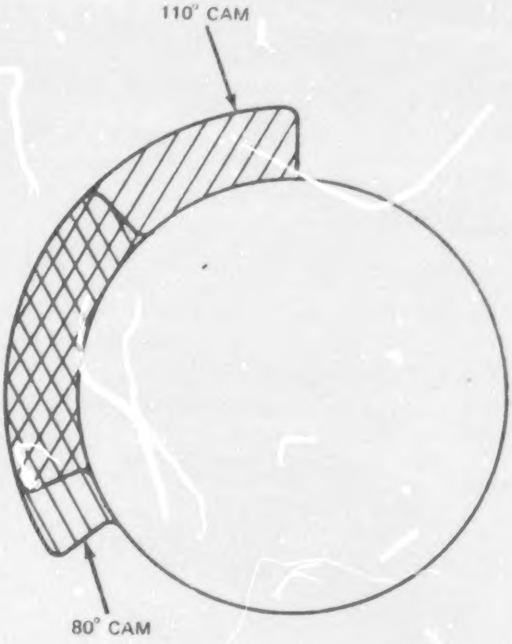
$$80^\circ + 45^\circ = 125^\circ$$

$$125^\circ - 110^\circ = 15^\circ$$

$$80^\circ - 15^\circ = 65^\circ$$

$$X = 65^\circ\,(.00476\ \tfrac{\text{sec}}{\circ})$$

$$X = 0.309\ \text{sec.}$$



CAMS

UNIT VII

ANSWERS TO PROBLEMS - INTRODUCTION TO THE GENEVA MECHANISM

1. Calculate the distance between the shafts of an 8-slot geneva wheel that has a driving crank length of 1 inch.

$$\ell_o = \frac{\ell_1}{\sin \frac{180^o}{n}}$$

$$\ell_o = \frac{1''}{\sin \frac{\pi}{n}} = \frac{1''}{\sin \frac{180^o}{8}}$$

1 Radians = 57.2^o

.398 Radians = 22.4^o

Therefore, $\ell_o = \frac{1''}{\sin (22.4^o)} = \frac{1''}{.924} = 1.08''$

2. How does the ratio of input and output velocity vary with the number of slots of a geneva wheel (averaged over long time periods)?

$\frac{\omega_1}{\omega_2} = n$

The larger the number of slots, the more the velocity will increase. The fewer the slots, the more the velocity will decrease.

3. What are some of the possible problems that one might encounter in driving geneva wheel mechanisms at high RPMs?

The wheel may jump the slots and distort the output.

4. The external geneva wheel has a greater dwell than drive time, while the opposite relationship is true for the internal device. For equal input velocities, which would you expect to experience lower acceleration and why?

The internal type gives lower acceleration because it has more time to reach the necessary velocity.

ANSWERS TO PROBLEMS - INTRODUCTION TO THE GENEVA MECHANISM

5. How many degrees does a 10-slot star wheel turn during each revolution of the driven member?

$$\theta = \frac{360^\circ}{n} = \frac{360^\circ}{10} = 36^\circ/\text{Revolution}$$

6. What is the dwell time for a 10-slot external geneva wheel mechanism?

$$\theta = \frac{360^\circ}{n} = \frac{360^\circ}{10} = 36^\circ$$

$$\text{Dwell time} = 360^\circ - 36^\circ = 224^\circ$$

7. What is the major advantage of the internal type as compared to the external type geneva mechanism?

The internal type gives lower acceleration and greater velocity.

CAMS

UNIT VII

ANSWERS TO PROBLEMS - LOADING GENEVA MECHANISMS

1. Calculate the length of the driven crank, ℓ_2, at 0 degrees and 90 degrees for a four-slot geneva wheel.

$$\ell_2 = \ell_1\sqrt{1 + m^2 - 2m\cos a}$$

$$m = \frac{1}{\sin\frac{180^\circ}{n}} = \frac{1}{\sin\frac{180^\circ}{4}} = \frac{1}{\sin 45^\circ} = \frac{1}{.707} = 1.41$$

0°: $\ell_2 = \ell_1\sqrt{1 + (2.0) - 2(1.41)(1)}$

$\ell_2 = \ell_1\sqrt{3.0 - 2.82} = \ell_1\sqrt{.18}$

$\ell_2 =$ [redacted] $.425\ \ell_1$

90°: $\ell_2 = \ell_1\sqrt{3.0 - 2(1.41)(0)}$

$\ell_2 = \ell_1\sqrt{3.0}$

$\ell_2 = 1.73\ \ell_1$

2. Calculate the length of the driven crank, ℓ_2, at 22.5° and 45° for a six-slot geneva wheel.

$$m = \frac{1}{\sin\frac{180^\circ}{n}} = \frac{1}{\sin\frac{3.14}{6}} = \frac{1}{\sin(.523)} = \frac{1}{\sin(29.8^\circ)}$$

$$m = \frac{1}{.496} = 2.02$$

22.5°: $\ell_2 = \ell_1\sqrt{1 + (4.1) - 2(2.02)(.925)}$

$\ell_1 = \ell_1\sqrt{5.1 - 3.74} = \ell_1\sqrt{1.36}$

$\ell_2 = 1.17\ \ell_1$

45°: $\ell_2 = \ell_1\sqrt{5.1 - 2(2.02)(.707)}$

$\ell_2 = \ell_1\sqrt{5.1 - 2.86} = \ell_1\sqrt{2.24}$

$\ell_2 = 1.495\ \ell_1$

3. What is the approximate angle at which the roller will first engage in the slot of an eight-slot geneva wheel mechanism?

$$\frac{360^\circ}{8} = 45^\circ$$

ANSWERS TO PROBLEMS - LOADING GENEVA MECHANISMS

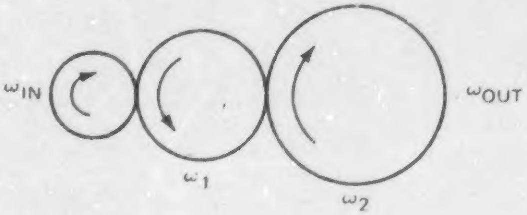
4. If a row of holes is to be drilled in a piece of steel plate by a semi-automatic machine tool, explain briefly how a geneva mechanism might be used to position the table of the machine tool.

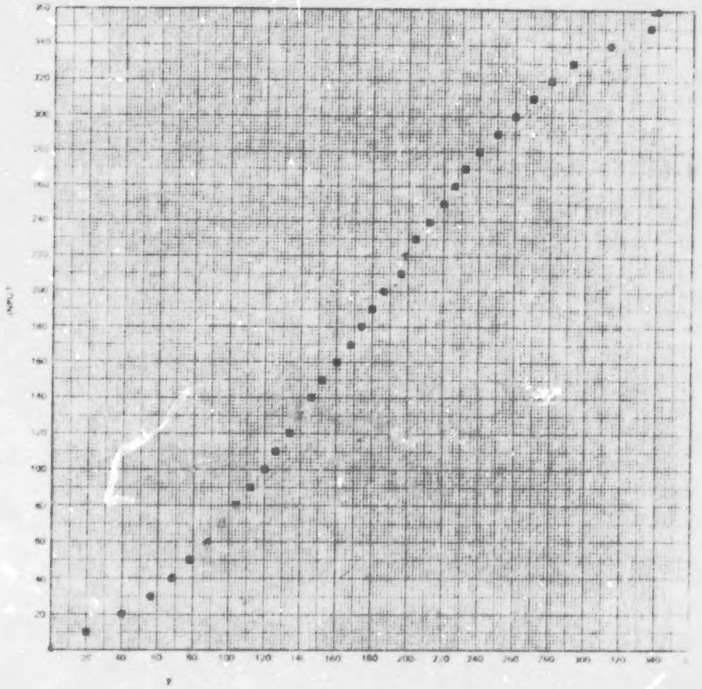
   The table could be connected to the driven wheel. As it rotates, the holes can be drilled during a dwell. The number of slots would vary with the number of holes to be drilled.

5. If a four-slot geneva mechanism is used to drive a six-slot geneva mechanism, describe the output rotation pattern in relation to a constant input. How are the input and output RPM related?

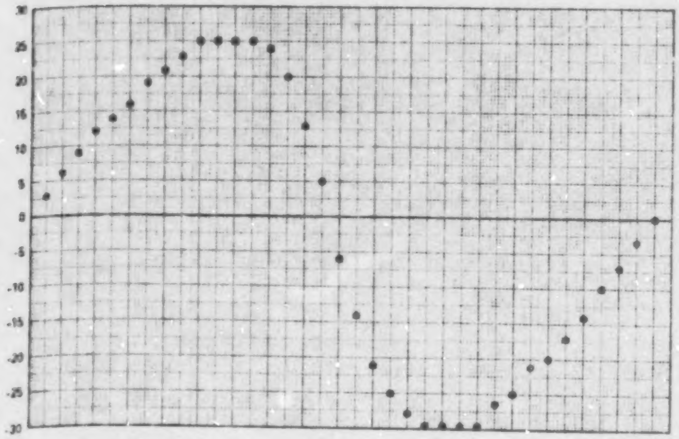
   The output would rotate in the same direction as the input.

$$\frac{\omega_1}{\omega_{out}} = \frac{n_1}{n_2}$$





ANSWERS TO PROBLEMS - LOADING GENEVA MECHANISMS



CAMS

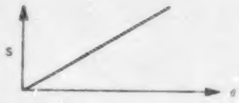
UNIT VII

TEST ANSWERS

1. a. 13
   b. 14
   c. 3
   d. 1
   e. 8
   f. 2
   g. 4
   h. 12
   i. 6
   j. 7
   k. 5
   l. 11
   m. 10
   n. 9

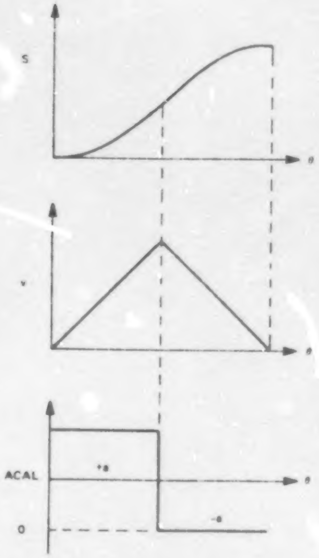
2.

UNIFORM MOTION

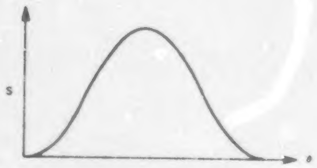


THE SLOPE OF THE UNIFORM MOTION CAN BE ZERO OR A CONSTANT VALUE, EITHER ONE OF WHICH IMPLIES ZERO ACCELERATION.

UNIFORMLY ACCELERATED AND DECELERATED MOTION



HARMONIC MOTION



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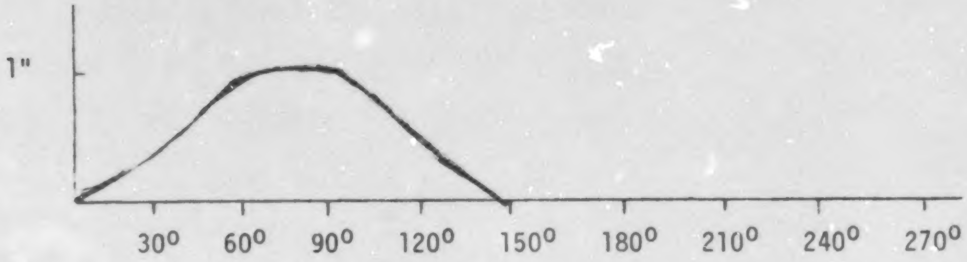
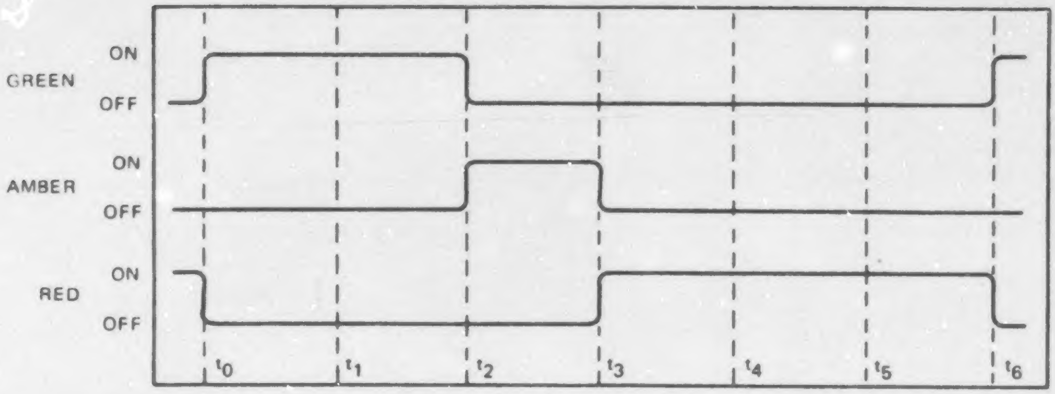
TEST ANSWERS

3.



4.

Second Case
Green – 1/3 Rev.
Amber – 1/6 Rev.
Red – 1/2 Rev.


GREEN
ON
OFF
AMBER
ON
OFF
RED
ON
OFF
t_0
t_1
t_2
t_3
t_4
t_5
t_6

TEST ANSWERS

5. a. $\frac{\omega 1}{\omega 2} = n$ The larger the number of slots, the more the velocity will increase. The fewer the slots, the more the velocity will decrease.

b. The wheel may jump the slots and distort the output.

c. The internal type gives lower acceleration and greater velocity.

6. $$m = \frac{1}{\sin \frac{180^o}{8}} = \frac{1}{0.38} = 2.613$$

n=8

$$\ell_2 = \ell_1 \sqrt{1 + 2.61^2 - 2\,(2.61) \cos 30^o}$$

$$\ell_2 = \ell_1 \sqrt{1 + 6.81 - 5.22\,(.866)}$$

$$= \ell_1 \sqrt{7.81 - 4.52}$$

$$\ell_2 = 1.81 \ \ell_1$$

CAMS

UNIT VII

MATHEMATICAL EXPRESSIONS

$y = Mx + b$

$M = \frac{\text{rise}}{\text{run}}$

$\Theta = 2\sin^{-1}\frac{y}{2r}$

$y = 2r\sin\frac{\Theta}{2}$

$f(x) = F\sin\theta$

$y = 2r\sin\frac{\Theta}{2}$

$\Theta = 2\sin^{-1}\left(\frac{y}{2r}\right)$

$\ell_2 = \ell_1\sqrt{1 + m^2 - 2m\cos\alpha}$ where $m = \frac{1}{\sin\frac{180^\circ}{n}}$ and n = No. of Slots

$a_1 = \ell_1\cos\alpha$

$b_2 = \ell_0 - \ell_1\cos\alpha$

$\ell_0 = \frac{\ell_1}{\sin\frac{180^\circ}{n}}$

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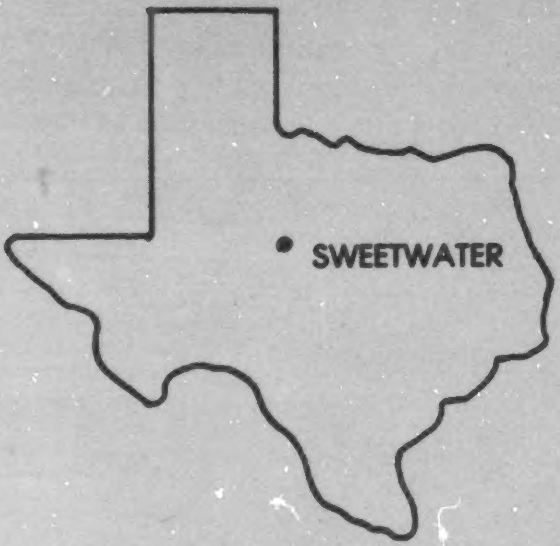

PART IV

TEXAS STATE TECHNICAL INSTITUTE
SWEETWATER, TEXAS

1984

U.S. DEPARTMENT OF EDUCATION
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MICROPROCESSOR AND INTERFACING

UNIT I

MICROPROCESSOR ARCHITECTURE

MICROPROCESSORS

UNIT I

OBJECTIVE

After completing this unit, the student should be able to explain the architecture of the 8080A, 8224, and 8228 IC's and the function of the pins on the IC's. The student should also be able to read a simple machine language program for its operation. This knowledge will be shown by completing assignment sheets, lab sheets, and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with microprocessors to their correct definitions.
2. Label each pin on the 8080A and describe its function.
3. Explain the function of each part of the clock generator (8224).
4. Explain how the system controller (8228) works in conjunction with the 8080A.
5. Describe how memory addresses are determined in the 8080A.
6. State a use for bidirectional bus driver.
7. List the function for each byte in an 8080A instruction.
8. Change 8080A memory addresses from hexadecimal code to binary.
9. List the addresses for the single and linked registers.
10. List three types of memory addresses.
11. State how the number of possible I/O devices are determined.
12. Name the three addressing modes.
13. Explain how mnemonic codes relate to op codes.
14. Explain how move instructions are coded.
15. Describe how the arithmetic instructions work.

SPECIFIC OBJECTIVES

16. Explain how rotate instructions work.
17. Differentiate between conditional and unconditional instructions.
18. Describe the function of special instructions.
19. Demonstrate the ability to
    - A. Use a microcomputer
    - B. Use a microcomputer for addition and subtraction.
    - C. Use a microcomputer with logical instructions.

MICROPROCESSORS

UNIT I

SUGGESTED ACTIVITIES

I. Instructor

- A. Provide students with objective sheets.
- B. Provide students with information, assignment, and lab sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information assignment and lab sheets.
- F. Demonstrate different microprocessors and emphasize their similarities.
- G. Demonstrate simple machine language programs.
- H. Assist students in wiring, troubleshooting, and use of their microcomputer.
- I. Give test.

II. Student

- A. Read objective sheet.
- B. Study information sheets.
- C. Complete assignment sheets.
- D. Complete lab sheets.
- E. Take test.

MICROPROCESSORS

UNIT I

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Information sheets.

   C. Assignment sheets.

   D. Lab sheets.

   E. Test.

   F. Answers to assignment sheets.

   G. Answers to test.

II. References

   A. Pasahow, Edward J., Microprocessors and Microcomputer, New York, New York, McGraw-Hill Book Co., 1981.

   B. Camp, Smay, Triska, Microprocessor Systems Engineering, Beaverton, Oregon, Matrix Publishers, 1979.

   C. Rony, Peter R., Introductory Experiments in Digital Electronic and 8080A Microcomputer Programming and Interfacing VI, Indianapolis, Indiana, Howard W. Sams & Co.

   D. Pasahow, Edward J., Microcomputer Interfacing, New York, New York, McGraw-Hill Book Co., 1981.

   E. Staugaard, Andrew C., Microprocessor Interfacing, Benton Harbor, Michigan, Heath Co., 1982.

   F. Hall, Douglas V. and Marybelle B., Experiments in Microprocessors and Digital System, New York, New York, McGraw-Hill Book Co., 1983.

   G. Brey, Barry B., Microprocessor Hardware Interfacing And Applications, Columbus, Ohio, Charles E. Merrill Publishing Co., 1984.

MICROPROCESSOR

UNIT I

PROCEDURE SHEET

______1. Study — Information Sheets.

______2. Study — Chapter 2, Microprocessor Architecture, Page 7-33, Microcomputer Interfacing, Pasahow.

______3. Complete — Assignment Sheet #1 - 8080A Architecture.

______4. Complete — Assignment Sheets #2 - The Clock Generator and System Controller.

______5. Complete — Assignment Sheet #3 - Problems Dealing with the Functioning of the Microprocessor.

______6. Stop — Have your instructor evaluate your assignment sheets. If your instructor is satisfied with your performance continue to step 7. Ohterwise repeat steps 1-6.

______7. Do — Lab Sheet #1 - Using a Microprocessor.

______8. Do — Lab Sheet #2 - Using a Microcomputer for Addition and Subtraction.

______9. Do — Lab Sheet #3 - Using Logical Instructions.

_____10. Stop — If your instructor is satisfied with the results of your lab sheets, continue with step 11. Otherwise consult with your instructor for additional work.

_____11. Review — Chapter 2, Information Sheets, Assignment Sheet, and Lab Sheets.

_____12. Complete — Unit test.

MICROPROCESSORS

UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Architecture - the structure of a computer's internal parts and the structure used to move command and data.

B. Bus - two-way lines connecting components.

C. Data bus - lines used to move information.

D. Control bus - lines that supply commands and timing to move data.

E. Address bus - lines that control where data is coming from and going to.

F. Timing signal - signals necessary to coordinate different internal functions.

G. Register - storage device that stores specific data.

H. Machine cycles - timing cycles during which operations occur.

I. Memory map - the memory organization for a computer system (RAM, ROM, EPROMETE).

J. Instruction - computer commands that can be categorized as data transfer, arithmetic, logical branching, input/output.

K. Direct addressing - a command made up of 3 bytes that gives a specific address to operate on (op code = 1 byte, address - 2 bytes).

L. Immediate addressing - two byte command that has the quantity to be operated on following the op code byte.

INFORMATION SHEET

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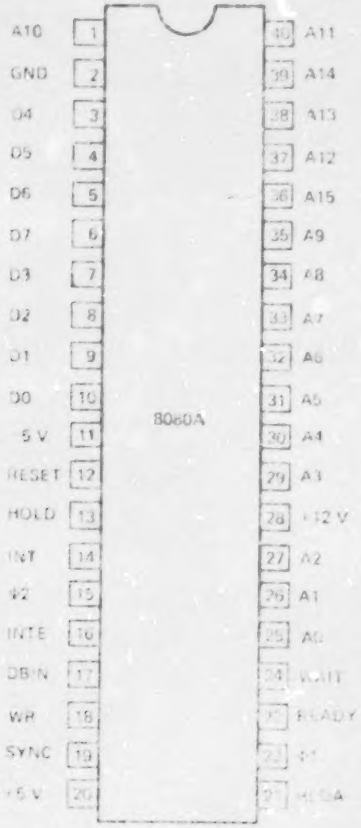
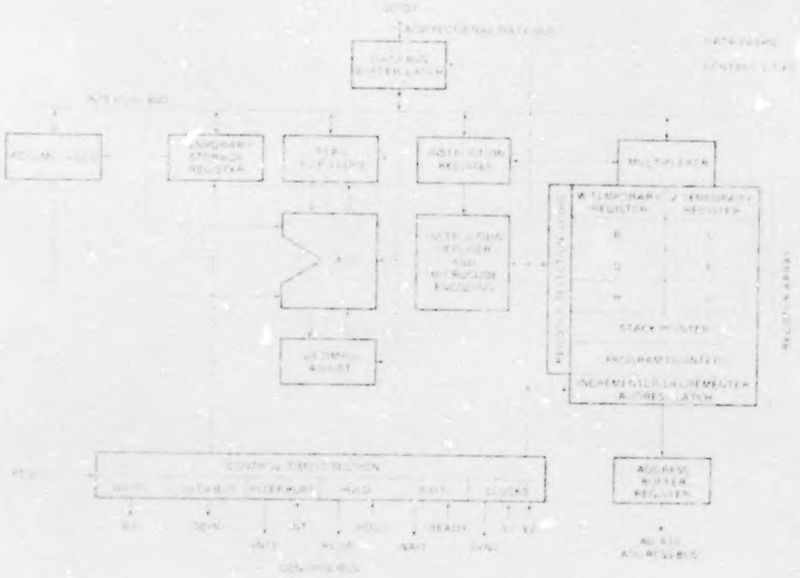
II. Microprocessor Unit (8080A)


A10 1
GND 2
D4 3
D5 4
D6 5
D7 6
D3 7
D2 8
D1 9
D0 10
-5 V 11
RESET 12
HOLD 13
INT 14
Φ2 15
INTE 16
DBIN 17
WR 18
SYNC 19
+5 V 20
8080A
40 A11
39 A14
38 A13
37 A12
36 A15
35 A9
34 A8
33 A7
32 A6
31 A5
30 A4
29 A3
28 +12 V
27 A2
26 A1
25 A0
24 WAIT
23 READY
22 Φ1
21 HLDA


D0-D7
BIDIRECTIONAL DATA BUS
DATA PATHS
CONTROL LINES
DATA BUS BUFFER/LATCH
ACCUMULATOR
TEMPORARY STORAGE REGISTER
FLAG FLIP FLOPS
INSTRUCTION REGISTER
MULTIPLEXER
W TEMPORARY REGISTER
Z TEMPORARY REGISTER
B
C
D
E
H
L
STACK POINTER
PROGRAM COUNTER
INCREMENTER/DECREMENTER ADDRESS LATCH
REGISTER SELECT
REGISTER ARRAY
INSTRUCTION DECODER AND MACHINE CYCLE ENCODING
DECIMAL ADJUST
TIMING AND CONTROL
CLOCKS
HOLD
WAIT
INTERRUPT
DATA BUS
RESET
WR
DBIN
INTE
INT
HLDA
HOLD
WAIT
READY
SYNC
Φ1 Φ2
ADDRESS BUFFER REGISTER
A0-A15
ADDRESS BUS
CONTROL BUS

INFORMATION SHEET

A. Data line

1. 0-D7 lines are bidirectional three-state lines.
2. I/0 data for the MPU use these lines.

B. Address lines

1. A0-A15 lines are output three state lines.
2. Addresses on these lines indicate binary addresses of memory to be read or written from or to.
3. These lines also designate I/0 devices to be used.

C. Ready line (input, low)

1. Set by external device to external timing control. Sets the WAIT state.
2. Unset by external device by setting line to high.

D. WAIT (output, high)

1. Signals when the 8080A is in a WAIT state.
2. Operations are suspended.

E. HOLD line (input, high)

1. Stops MPU after completing the instruction its working on.
2. Data and addresses buses are open to be used by peripheral devices.
3. Set to low, 8080A reverses processing.

F. HLDA (output, high)

1. Set when HOLD is high.
2. Used to control external devices.
3. Goes low when HOLD goes low.

INFORMATION SHEET

G. Reset line (input, high)

   1. If set for three clock cycles the MPU zeros all registers.

   2. Statue register stays same.

   3. When set low program register is set to 0000_{16}; therefore will begin executing instructions in that cell.

H. Arithmetic logic unit (ALU) - executes addition, subtraction, and Boolean operations.

I. Instruction decoder and microcode encoder

   1. Timing sequences produced.

   2. Instructions interpreted.

J. DBIN (output, high) - addressed datum is accepted by the data bus at this time.

K. Write or stroke line ($\overline{WR}$, output low) - output datum is on the data bus.

L. Interrupt (input, high) - set by external logic.

M. INTE (output, high) - indicates 8080A is in interrupt mode.

N. Ten programmable registers

   1. A is the 8 bit accumulator.

   2. B, C, D, E, H, and L are secondary accumulation.

      a. Can be linked to provide 16 bit address pointers.

      b. HL is the primary memory pointer.

   3. Program status word

      a. Reflects result of arithmetic and logical instructions.

      b. Bit 7 - sign flag is 1 if the result in A is negative.

      c. Bit 6 - zero flag is 1 if the result in A is zero.

d. Bit 4 - auxiliary carry is one if there was a carry out of bit 3 to bit 4 of A.

e. Bit 2 - parity will be one if the count in A is odd.

f. Bit 0 - carry will be 1 if A had a carry from the MSB in A.

4. Stack pointer

   a. Has the address of the next memory cell to be popped (obtain data).

   b. Data may also be pushed to memory through this address.

5. Program counter - holds the address of the next instruction to be processed.

O. Timing control

1. Machine cycle is made up of 5 parts: T1-T5

2. T1-T3 used from memory references.

3. T4-T5 used for MPU operations.

4. During T1-T3 are used to fetch an instruction.

5. T4 the program counter is incremented and the fetched instruction decoded.

6. T5 is optional and used if MPU needs more time.

7. During 2 the MPU commands an operation to be performed by the 8 bit code on the data bus.

8. The 8 bit code on the data bus:

   a. D0 - INTA acknowledge interrupt.

   b. D1 - $\overline{WR}$ data bus will be used for write.

   c. D2 - STACK the address bus now builds stack pointer address.

   d. D3 - HLTA signal for HALT.

   e. D4 - OUT address bits indicate output device that will accept.

   f. D5 - M1 MPU is in fetch cycle of the first byte of an instruction.

INFORMATION SHEET

g. D6 - INP address bus indicates input device that will place data bus when DBIU goes high.

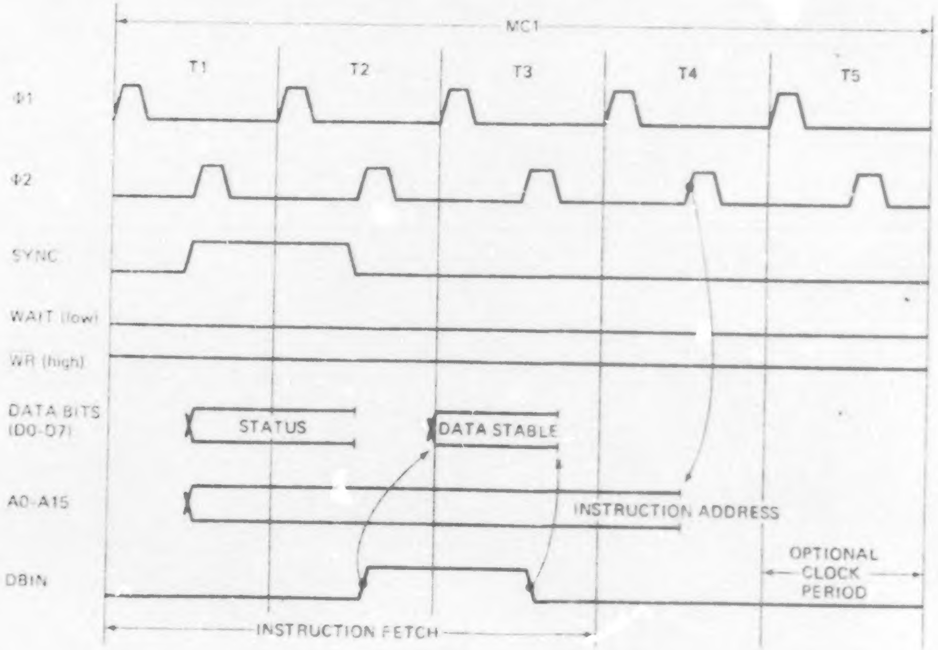
h. D7 - MEMR data bus will be used to read from memory.

(NOTE: These micro instructions will be performed when there is a one. The exception is D1; $\overline{WR}$ must be low to write.)

EXAMPLE: Instruction Fetching

Type of microinstruction	Address bus status code (hexadecimal)
Instruction fetch	A2
Memory read	82
Memory write	00
Stack read	86
Stack write	04
Input read	42
Output write	10
Interrupt acknowledge	23
Halt acknowledge	8A or 0A
Interrupt acknowledge while halted	2B or 23

EXAMPLES: Instruction Fetching


MC1
T1
T2
T3
T4
T5
Φ1
Φ2
SYNC
WAIT (low)
WR (high)
DATA BITS (D0-D7)
STATUS
DATA STABLE
A0-A15
INSTRUCTION ADDRESS
DBIN
OPTIONAL CLOCK PERIOD
INSTRUCTION FETCH

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INFORMATION SHEET

Single-Byte Instruction Fetching

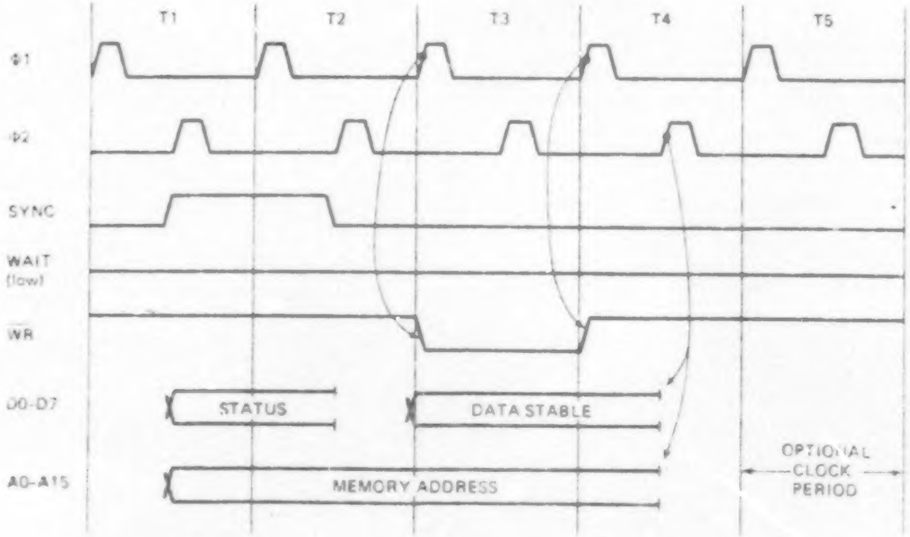
T1:
1. Leading edge of Φ2 causes SYNC to rise, marking the period of T1.
2. WAIT is low, so the MPU is not in the wait state.
3. $\overline{WR}$ is high. Data is to be read (not written) from memory.
4. Data bits are set with the status code.
   $\overline{WO}$ (D1) high. The MPU is expecting an input.
   M1 (D5) high. The instruction is in the fetch cycle.
   MEMR (D7) high. Input from memory.
5. The appropriate memory address is set on the address lines, A0–A15.

T2:
1. Memory uses Φ1 ANDed with SYNC to read status from the data bus.
2. DBIN high causes the data bus to be ready to receive input. (The signal stays high until the rising edge of Φ2 during T3.)

T3:
1. MPU stores the instruction in the instruction register where the control section will interpret it.
2. The data lines are floated during T3, making it available to external logic.

T4:
1. The data bus is floated during T4.
2. The program counter is incremented.

EXAMPLE: Writing Memory Data


T1
T2
T3
T4
T5
Φ1
Φ2
SYNC
WAIT (low)
$\overline{WR}$
D0-D7
A0-A15
STATUS
DATA STABLE
MEMORY ADDRESS
OPTIONAL CLOCK PERIOD

INFORMATION SHEET

Writing Data in Memory

T1:	1. Leading edge of Φ2 causes SYNC to rise, marking the period as T1. 2. WAIT is low, so the MPU is not in the wait state. 3. $\overline{\text{WR}}$ is high until the time to write. 4. All data bits are zero. 5. The appropriate memory address is set on the address lines, A0–A15.
T2:	1. Memory uses Φ2 ANDed with SYNC to read status from the data bus. 2. DBIN remains low.
T3:	1. $\overline{\text{WR}}$ goes low. 2. The data is transferred from memory to the data bus and then to the processor.
T4:	1. The data and address buses are floated during T4. 2. The program counter is incremented.

P. Power supplies to drive the chip: +5, +12V, -5V and grid.

III. Clock generator IC (8224)

A. Provides ϕ1 and ϕ2 inputs for the 8080A.

B. Provides properly sychronized READY and RESET inputs for the 8080A.

C. XTAL - the clock period is 500 nanoseconds and the crystal frequency of the 8224 is 18 megahertz.

D. Control signals

1. $\overline{\text{RESIN}}$ input is converted to RESET (output) for the 8080A.

2. RDYIN input is converted to READY for the 8080A.

3. $\overline{\text{STSTB}}$ output for the system controller (8228) and produced by the 8080A SYNC.

E. Oscillator (OSC) crystal oscillator waveform output.

F. Control signal (SYNC) input signal from the 8080A.

G. External crystal connection (XTAL1, XTAL2, 7ANK) inputs.

H. Clock signals (I1, I2) outputs.

I. TTL - compatible clock (ITTL) output.

INFORMATION SHEET

IV. System controller IC (8228)

A. D0-D7 bidirectional lines used to control data from the 8080A to the system.

B. DB0-DB7 bidirectional lines for the system bus.

C. Bus control lines -

1. $\overline{WR}$, DBIN, HLDH inputs are combined with the corresponding 8080A signals to generate 8228 control.

2. I/O read and write - ($\overline{I/OR}$ and $\overline{I/OW}$) controls read and write output.

3. Interrupt ($\overline{INT}$) interrupt acknowledge output.

4. Memory read and write ($\overline{MEMR}$ and $\overline{MEMW}$) outputs to controls reading and writing.

5. Status strobe ($\overline{STSTB}$) input that is synchronized with $\overline{MEMR}$.

6. Data output strobe ($\overline{WR}$) input that causes $\overline{MEMW}$ to direct data to memory.

D. Power supplied by +5V and ground lines.

V. Memory

A. With a 16 bit address there are 65,536 addressable addresses in the 8080A ($2^{16} = 65536$).

B. These are organized into 1K groups where 1K is actually equal to 1024 memory locations.

C. A 64K memory actually has 65536 addresses.

D. These addresses can be

1. RAM
2. ROM
3. PROM
4. EPROM

E. To convert hexadecimal four digit code to binary code requires a decoder (4 → 16).

F. The 8080A uses a 1-of-8 decoder. This means it takes 8-8025 decoders to address a particular 1K = group.

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G. To read a memory

1. The address is on the address lines.
2. $\overline{\text{MEMR}}$ is low.
3. $\overline{\text{CS}}$ goes low for the coded upper six bits.
4. The data in the particular memory is then available on the data lines.

H. To write a memory.

1. A NAND is used to code the upper six bits.
2. The chip select ($\overline{\text{CS}}$) line is low.
3. It takes 64 gates to handle 64K.

VI. Bidirectional bus drivers

A. Used to drive loads for the MPU.

B. It takes two 8215's to handle an 8 bit bus.

C. Chip select is controlled as in memory select.

D. Direction of flow is determined by $\overline{\text{DIEN}}$.

VII. 8080A Instructions may be:

A. One byte. First is command to:

1. Transfer
2. Halt
3. Input data
4. Add, etc.

B. Two byte. Second is:

1. Data - it is operand or
2. Device - which one.

C. Third byte

1. Two byte address
2. Two data bytes

VIII. Memory designation has addresses for 0-65536 or 0000_{16} to $FFFF_{16}$.

IX. Register addresses. The seven registers have addresses of:

INFORMATION SHEET

Single Registers	
B	0
C	1
D	2
E	3
H	4
L	5
A	7

Linked Registers	
BC	0
DE	1
HL	2
PSW/A	3

X. Memory addressing

   A. 3 bytes by instruction

      1. 1 Byte - op code
      2. 2 & 3 byte - address

   B. 2 bytes by linked registers

   C. 2 bytes by stack pointers

XI. I/O devices can number up to 256. There is a 1 byte address ($2^8 = 256$).

XII. There are three addressing modes

   A. Direct addressing

      1. 1 byte op code
      2. 2 & 3 byte addresses

   B. Register addressing

      1. 1 byte op code
      2. Example: move one register to another

   C. Immediate addressing

      1. 1 byte - op code
      2. Next byte - what is to be operated on

XIII. Encoding and decoding

   A. Two hexadecimal parts

      1. Op code field
      2. Operand field

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B. Mnemonic code

1. 3 letter command code
2. Useful only to programmer
3. Machine translate mneumonic to hexadecimal code

XIV. Instruction set

A. Move instructions

Move Group*

Mnemonic	Description	Number of bytes
MOV D, S	(S) → D	1
MOV M, S	(S) → M	1
MOV D, M	(M) → D	1
MVI D, B	B → D	2
LDAX B	(M(BC)) → A	1
LDAX D	(M(DE)) → A	1
XCHG	(H) ↔ (D), (L) ↔ (E)	1
LXI D, BB	(BB) → RP	3
LHLD	(M) → L, (M + 1) → H	3
LDA	(M) → A	3
STAX B	(A) → M (BC)	1
STAX D	(A) → M (DE)	1
SHLD	(L) → M, (H) → M + 1	3
STA	(A) → M	3

* Flag bits are not affected by these instructions.

EXAMPLE:

1. LDA. This instruction will move the contents of the address specified by the second two tytes to place them in the accumulator. The op code is in the 1st byte.

2. MUID B. This instruction moves the contents of register B to and then in register D.

B. Arithmetic instructions

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B. Arithmetic instructions

Arithmetic Group

Mnemonic	Description	Flags					Number of bytes
		C	Ac	Z	S	P	
ADD S	(S) + (A) → A	X	X	X	X	X	1
ADD M	(M) + (A) → A	X	X	X	X	X	1
ADC S	(S) + (A) + (CARRY) → A	X	X	X	X	X	1
ADC M	(M) + (A) + (CARRY) → A	X	X	X	X	X	1
SUB S	(A) − (S) → A	X	X	X	X	X	1
SUB M	(A) − (M) → A	X	X	X	X	X	1
SBB S	(A) − (S) − (CARRY) → A	X	X	X	X	X	1
SBB M	(A) − (M) − (CARRY) → A	X	X	X	X	X	1
DAD	(HL) + (RP) → HL	X					1
INR S	(S) + 1 → S		X	X	X	X	1
INR M	(M) + 1 → M		X	X	X	X	1
INX	(RP) + 1 → RP						1
DCR S	(S) − 1 → S		X	X	X	X	1
DCR M	(M) − 1 → M		X	X	X	X	1
DCX	(RP) − 1 → RP						1
DAA	Decimal Adjust	X	X	X	X	X	1
CMA	$(\bar{A})$ → A						1
STC	1 → CARRY	1					1
CMC	$\overline{(\text{CARRY})}$ → CARRY	X					1
ADI	(A) + B → A	X	X	X	X	X	2
ACI	(A) + B + (CARRY) → A	X	X	X	X	X	2
SUI	(A) − B → A	X	X	X	X	X	2
SBI	(A) − B − (CARRY) → A	X	X	X	X	X	2
ANA S	(S) AND (A) → A	0	X	X	X	X	1
ANA M	(M) AND (A) → A	0	X	X	X	X	1
XRA S	(S) ⊙ (A) → A	0	X	X	X	X	1
XRA M	(M) ⊙ (A) → A	0	X	X	X	X	1
ORA S	(S) OR (A) → A	0	X	X	X	X	1
ORA M	(M) OR (A) → A	0	X	X	X	X	1
CMP S	COMPARE	X	X	X	X	X	1
CMP M	COMPARE	X	X	X	X	X	1
ANI	(A) AND B → A	0	X	X	X	X	2
XRI	(A) ⊙ B → A	0	0	X	X	X	2
ORI	(A) OR B → A	0	0	X	X	X	2
CPI	COMPARE	X	X	X	X	X	2

EXAMPLE:

1. DCRS. This instruction will subtract one from the (S) register and place the result in the (S) register.

2. ACI. This instruction adds the contents of address B to the accumulator with carry and leaves the result in the accumulator.
   (NOTE: The state of the flag bits is very important to the correct execution of the command.)

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C. Rotate instructions

Rotate Group

Mnemonic	Description	Flags					Number of bytes
		C	Ac	Z	S	P	
RLC	Rotate A left	X					1
RRC	Rotate A right	X					1
RAL	Rotate A left through carry	X					1
RAR	Rotate A right through carry	X					1

EXAMPLE:

1. RLC. Register A rotates one positon to the left with the MSB appearing in the carry bit and LSB.
2. RAL. Register A rotates one position to the left leaving the MSB in the carry and the carry moves to the LSB.

D. Conditional and unconditional instructions

Jump, Call, and Return Group*

Mnemonic	Description	Number of bytes
JMP	Jump	3
JNZ	Jump (zero) = 0	3
JZ	Jump (zero) = 1	3
JNC	Jump (carry) = 0	3
JC	Jump (carry) = 1	3
JPO	Jump (parity) = 0	3
JPE	Jump (parity) = 1	3
JP	Jump (sign) = 0	3
JM	Jump (sign) = 1	3
FCHL	(HL) → PC	1
CALL	Call	3
CNZ	Call (zero) = 0	3
CZ	Call (zero) = 1	3
CNC	Call (carry) = 0	3
CC	Call (carry) = 1	3
CPO	Call (parity) = 0	3
CPE	Call (parity) = 1	3
CP	Call (sign) = 0	3
CM	Call (sign) = 1	3
RET	Return	1
RNZ	Return (zero) = 0	1
RNC	Return (carry) = 0	1
RC	Return (carry) = 1	1
RPO	Return (parity) = 0	1
RPE	Return (parity) = 1	1
RP	Return (sign) = 0	1
RM	Return (sign) = 1	1

* Flag bits are not affected by these instructions.

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EXAMPLE:

1. Unconditional. Always performed. JMP. The first byte is the op code while the next two bytes will be the address of the next instruction. These two bytes are put into the program counter.

2. Conditional. RNZ. Returns control to program counter if the Z flag is zero. Otherwise continue performing instructions.

E. Special instructions

Table 2-17
I/O and Miscellaneous Group*

Mnemonic	Description	Number of bytes
PUSH	(RP) → STACK	1
POP	(STACK) → RP	1
XTHL	(L) → (M(SP)), (H) → (M(SP + 1))	1
SPHL	(HL) → SP	1
NOP	(PC) + 1 → PC	1
HLT	HALT	1
OUT	OUTPUT	2
IN	INPUT	2
DI	0 → INTE	1
EI	1 → INTE	1
RST	RESTART	1

*Flag bits are not affected by these instructions.

EXAMPLE:

1. SPHL. The addresses contained in register H and L are placed in the stack pointer.

2. NOP. Increments the contents of the program counter by one.

XV. 8080 Operation Codes

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XV. 8080 Operation Codes

Alphabetical Listing of 8080A Operation Codes

Mnemonic	Operation Code	Bytes	Description	Clock Periods
ACI	CE	2	(A)+(DATA)+(CARRY) → A	7
ADC A	8F	1	(A)+(A)+CARRY → A	4
ADC B	88	1	(A)+(B)+(CARRY) → A	4
ADC C	89	1	(A)+(C)+(CARRY) → A	4
ADC D	8A	1	(A)+(D)+(CARRY) → A	4
ADC E	8B	1	(A)+(E)+(CARRY) → A	4
ADC H	8C	1	(A)+(H)+(CARRY) → A	4
ADC L	8D	1	(A)+(L)+CARRY → A	4
ADC M	8E	1	(A)+(M)+CARRY → A	7
ADD A	87	1	(A)+(A) → A	4
ADD B	80	1	(A)+(B) → A	4
ADD C	81	1	(A)+(C) →	4
ADD D	82	1	(A)+(D) → A	4
ADD E	83	1	(A)+(E) → A	4
ADD H	84	1	(A)+(H) → A	4
ADD L	85	1	(A)+(L) → A	4
ADD M	86	1	(A)+(M) → A	7
ADI	C6	2	(A)+(DATA) → A	7
ANA A	A7	1	(A) AND (A) → A	4
ANA B	A0	1	(A) AND (B) → A	4
ANA C	A1	1	(A) AND (C) → A	4
ANA D	A2	1	(A) AND (D) → A	4
ANA E	A3	1	(A) AND (E) → A	4
ANA H	A4	1	(A) AND (H) → A	4
ANA L	A5	1	(A) AND (L) → A	4
ANA M	A6	1	(A) AND (M) → A	7
ANI	E6	2	(A) AND (DATA) → A	7
CALL	CD	3	(PCH) → (SP)−1, (PCL) → (SP)−2, (SP)−2 → SP, ADDR → PC	17
CC	DC	3	CALL if CARRY=1	11/17
CM	FC	3	CALL if SIGN=1	11/17
CMA	2F	1	$(\overline{A}) \rightarrow A$ (1's complement)	4
CMC	3F	1	$\overline{(\text{CARRY})} \rightarrow$ CARRY	4
CMP A	BF	1	(A)−(A) set condition bits, $A_r = A_i$	4
CMP B	B8	1	(A)−(B) set condition bits, $A_r = A_i$	4
CMP C	B9	1	(A)−(C) set condition bits, $A_r = A_i$	4
CMP D	BA	1	(A)−(D) set condition bits, $A_r = A_i$	4
CMP E	BB	1	(A)−(E) set condition bits, $A_r = A_i$	4
CMP H	BC	1	(A)−(H) set condition bits, $A_r = A_i$	4
CMP L	BD	1	(A)−(L) set condition bits, $A_r = A_i$	4
CMP M	BE	1	(A)−(M) set condition bits, $A_r = A_i$	7
CNC	D4	3	CALL if CARRY=0	11/17

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XV. 8080 Operation Codes

Alphabetical Listing of 8080A Operation Codes

Mnemonic	Operation Code	Bytes	Description	Clock Periods
CNZ	C4	3	CALL if ZERO=0	11/17
CP	F4	3	CALL if SIGN=0	11/17
CPE	EC	3	CALL if PARITY=1	11/17
CPI	FE	2	(A)−(DATA) set condition bits, $A_f = A_i$	7
CPO	E4	3	CALL if PARITY=0	11/17
CZ	CC	3	CALL if ZERO=1	11/17
DAA	27	1	Decimal adjust A	4
DAD B	09	1	(HL)+(BC) → HL	10
DAD D	19	1	(HL)+(DE) → HL	10
DAD H	29	1	(HL)+(HL) → HL	10
DAD SP	39	1	(HL)+(SP) → HL	10
DCR A	3D	1	(A)−1 → A	5
DCR B	05	1	(B)−1 → B	5
DCR C	0D	1	(C)−1 → C	5
DCR D	15	1	(D)−1 → D	5
DCR E	1D	1	(E)−1 → E	5
DCR H	25	1	(H)−1 → H	5
DCR L	2D	1	(L)−1 → L	5
DCR M	35	1	(M)−1 → M	10
DCX B	0B	1	(BC)−1 → BC	5
DCX D	1B	1	(DE)−1 → DE	5
DCX H	2B	1	(HL)−1 → HL	5
DCX SP	3B	1	(SP)−1 → SP	5
DI	F3	1	0 → INTE	4
EI	FB	1	1 → INTE	4
HLT	76	1	Stop processor	7
IN	DB	2	Input → A	10
INR A	3C	1	(A)+1 → A	5
INR B	04	1	(B)+1 → B	5
INR C	0C	1	(C)+1 → C	5
INR D	14	1	(D)+1 → D	5
INR E	1C	1	(E)+1 → E	5
INR H	24	1	(H)+1 → H	5
INR L	2C	1	(L)+1 → L	5
INR M	34	1	(M)+1 → M	10
INX B	03	1	(BC)+1 → BC	5
INX D	13	1	(DE)+1 → DE	5
INX H	23	1	(HL)+1 → HL	5
INX SP	33	1	(SP)+1 → SP	5
JC	DA	3	Jump if CARRY=1	10
JM	FA	3	Jump if SIGN=1	10
JMP	C3	3	Jump	10
JNC	D2	3	Jump if CARRY=0	10
JNZ	C2	3	Jump if ZERO=0	10
JP	F2	3	Jump if SIGN=0	10
JPE	EA	3	Jump if PARITY=1	10
JPO	E2	3	Jump if PARITY=0	10
JZ	CA	3	Jump if ZERO=1	10
LDA	3A	3	(ADDR) → A	13

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XV. 8080 Operation Codes

Alphabetical Listing of 8080A Operation Codes

Mnemonic	Operation Code	Bytes	Description	Clock Periods
LDAX B	0A	1	(Address=(BC)) → A	7
LDAX D	1A	1	(Address=(DE)) → A	7
LHLD	2A	3	(ADDR) → L,(ADDR+1) → H	16
LXI B	01	3	(DATA) → BC	10
LXI D	11	3	(DATA) → DE	10
LXI H	21	3	(DATA) → HL	10
LXI SP	31	3	(DATA) → SP	10
MOV A,A	7F	1	(A) → A	5
MOV A,B	78	1	(B) → A	5
MOV A,C	79	1	(C) → A	5
MOV A,D	7A	1	(D) → A	5
MOV A,E	7B	1	(E) → A	5
MOV A,H	7C	1	(H) → A	5
MOV A,L	7D	1	(L) → A	5
MOV A,M	7E	1	(M) → A	7
MOV B,A	47	1	(A) → B	5
MOV B,B	40	1	(B) → B	5
MOV B,C	41	1	(C) → B	5
MOV B,D	42	1	(D) → B	5
MOV B,E	43	1	(E) → B	5
MOV B,H	44	1	(H) → B	5
MOV B,L	45	1	(L) → B	5
MOV B,M	46	1	(M) → B	7
MOV C,A	4F	1	(A) → C	5
MOV C,B	48	1	(B) → C	5
MOV C,C	49	1	(C) → C	5
MOV C,D	4A	1	(D) → C	5
MOV C,E	4B	1	(E) → C	5
MOV C,H	4C	1	(H) → C	5
MOV C,L	4D	1	(L) → C	5
MOV C,M	4E	1	(M) → C	7
MOV D,A	57	1	(A) → D	5
MOV D,B	50	1	(B) → D	5
MOV D,C	51	1	(C) → D	5
MOV D,D	52	1	(D) → D	5
MOV D,E	53	1	(E) → D	5
MOV D,H	54	1	(H) → D	5
MOV D,L	55	1	(L) → D	5
MOV D,M	56	1	(M) → D	7
MOV E,A	5F	1	(A) → E	5
MOV E,B	58	1	(B) → E	5
MOV E,C	59	1	(C) → E	5
MOV E,D	5A	1	(D) → E	5
MOV E,E	5B	1	(E) → E	5
MOV E,H	5C	1	(H) → E	5
MOV E,L	5D	1	(L) → E	5
MOV E,M	5E	1	(M) → E	7
MOV H,A	67	1	(A) → H	5
MOV H,B	60	1	(B) → H	5
MOV H,C	61	1	(C) → H	5

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XV. 8080 Operation Codes

Alphabetical Listing of 8080A Operation Codes

Mnemonic	Operation Code	Bytes	Description	Clock Periods
MOV H,D	62	1	(D) → H	5
MOV H,E	63	1	(E) → H	5
MOV H,H	64	1	(H) → H	5
MOV H,L	65	1	(L) → H	5
MOV H,M	66	1	(M) → H	7
MOV L,A	6F	1	(A) → L	5
MOV L,B	68	1	(B) → L	5
MOV L,C	69	1	(C) → L	5
MOV L,D	6A	1	(D) → L	5
MOV L,E	6B	1	(E) → L	5
MOV L,H	6C	1	(H) → L	5
MOV L,L	6D	1	(L) → L	5
MOV L,M	6E	1	(M) → L	7
MOV M,A	77	1	(A) → M	7
MOV M,B	70	1	(B) → M	7
MOV M,C	71	1	(C) → M	7
MOV M,D	72	1	(D) → M	7
MOV M,E	73	1	(E) → M	7
MOV M,H	74	1	(H) → M	7
MOV M,L	75	1	(L) → M	7
MVI A	3E	2	DATA → A	7
MVI B	06	2	DATA → B	7
MVI C	0E	2	DATA → C	7
MVI D	16	2	DATA → D	7
MVI E	1E	2	DATA → E	7
MVI H	26	2	DATA → H	7
MVI L	2E	2	DATA → L	7
MVI M	36	2	DATA → M	10
NOP	00	1	No operation	4
ORA A	B7	1	(A) OR (A) → A	4
ORA B	B0	1	(A) OR (B) → A	4
ORA C	B1	1	(A) OR (C) → A	4
ORA D	B2	1	(A) OR (D) → A	4
ORA E	B3	1	(A) OR (E) → A	4
ORA H	B4	1	(A) OR (H) → A	4
ORA L	B5	1	(A) OR (L) → A	4
ORA M	B6	1	(A) OR (M) → A	7
ORI	F6	2	(A) OR (DATA) → A	7
OUT	D3	2	(A) → output	10
PCHL	E9	1	(HL) → PC	5
POP A	F1	1	(STACK) → A-PSW	10
POP B	C1	1	(STACK) → BC	10
POP D	D1	1	(STACK) → DE	10
POP H	E1	1	(STACK) → HL	10
PUSH A	F5	1	(A-PSW) → STACK	11
PUSH B	C5	1	(BC) → STACK	11
PUSH D	D5	1	(DE) → STACK	11
PUSH H	E5	1	(HL) → STACK	11
RAL	17	1	Rotate A left through CARRY, (CARRY) → A_0	4

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XV. 8080 Operation Codes

Alphabetical Listing of 8080A Operation Codes

Mnemonic	Operation Code	Bytes	Description	Clock Periods
RAR	1F	1	Rotate A right through CARRY, (CARRY) → A_7	4
RC	D8	1	Return if CARRY=1	5/11
RET	C9	1	Return	10
RLC	07	1	Rotate A left, (A_7) → CARRY	4
RM	F8	1	Return if SIGN=1	5/11
RNC	D0	1	Return if CARRY=0	5/11
RNZ	C0	1	Return if ZERO=0	5/11
RP	F0	1	Return if SIGN=0	5/11
RPE	E8	1	Return if PARITY=1	5/11
RPO	E0	1	Return if PARITY=0	5/11
RRC	0F	1	Rotate A right, (A_0) → CARRY	4
RST 0	C7	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 00_{16} → PC	11
RST 1	CF	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 08_{16} → PC	11
RST 2	D7	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 10_{16} → PC	11
RST 3	DF	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 18_{16} → PC	11
RST 4	E7	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 20_{16} → PC	11
RST 5	EF	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 28_{16} → PC	11
RST 6	F7	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 30_{16} → PC	11
RST 7	FF	1	(PCH) → ((SP)−1), (PCL) → ((SP)−2), (SP)+2 → SP, 38_{16} → PC	11
RZ	C8	1	Return if ZERO=1	5/11
SBB A	9F	1	(A)−(A)−CARRY → A	4
SBB B	98	1	(A)−(B)−CARRY → A	4
SBB C	99	1	(A)−(C)−CARRY → A	4
SBB D	9A	1	(A)−(D)−CARRY → A	4
SBB E	9B	1	(A)−(E)−CARRY → A	4
SBB H	9C	1	(A)−(H)−CARRY → A	4
SBB L	9D	1	(A)−(L)−CARRY → A	4
SBB M	9E	1	(A)−(M)−CARRY → A	7
SBI	DE	2	(A)−DATA−CARRY → A	7
SHLD	22	3	(L) → ADDR, (H) → ADDR+1	16
SPHL	F9	1	(HL) → SP	5
STA	32	3	(A) → ADDR	13
STAX B	02	1	(A) → Address=(BC)	7
STAX D	12	1	(A) → Address=(DE)	7
STC	37	1	1 → CARRY	4

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XV. 8080 Operation Codes

Alphabetical Listing of 8080A Operation Codes

Mnemonic	Operation Code	Bytes	Description	Clock Periods
SUB A	97	1	(A)−(A) → A	4
SUB B	90	1	(A)−(B) → A	4
SUB C	91	1	(A)−(C) → A	4
SUB D	92	1	(A)−(D) → A	4
SUB E	93	1	(A)−(E) → A	4
SUB H	94	1	(A)−(H) → A	4
SUB L	95	1	(A)−(L) → A	4
SUB M	96	1	(A)−(M) → A	7
SUI	D6	2	(A)−(DATA) → A	7
XCHG	EB	1	(H) ↔ (D), (L) ↔ (E)	4
XRA A	AF	1	(A) Exclusive OR (A) → A	4
XRA B	A8	1	(A) Exclusive OR (B) → A	4
XRA C	A9	1	(A) Exclusive OR (C) → A	4
XRA D	AA	1	(A) Exclusive OR (D) → A	4
XRA E	AB	1	(A) Exclusive OR (E) → A	4
XRA H	AC	1	(A) Exclusive OR (H) → A	4
XRA L	AD	1	(A) Exclusive OR (L) → A	4
XRA M	AE	1	(A) Exclusive OR (M) → A	7
XRI	EE	2	(A) Exclusive OR (DATA) → A	7
XTHL	E3	1	(L) → (SP), (H) → ((SP)+1)	18

Legend:

( ):	Contents of register or memory location
→:	Transfer
+:	Plus
−:	Minus
PC:	Program counter
PCL:	Lower byte of PC
PCH:	Higher byte of PC
SP:	Stack pointer
$\overline{A}$:	Complement of A
A_i:	Initial contents of A (before instruction execution)
A_f:	Final contents of A (after instruction execution)
A_0:	Least significant bit of A
A_7:	Most significant bit of A
INTE:	Interrupt enable flip-flop
ADDR:	Memory address bytes of the instruction
DATA:	Data byte of the instruction
CARRY:	Carry bit
$\overline{\text{CARRY}}$:	Complement of CARRY
M:	The memory address in HL register pair
SIGN:	Sign status bit
ZERO:	Zero status bit
PARITY:	Parity status bit
PSW:	Program status word

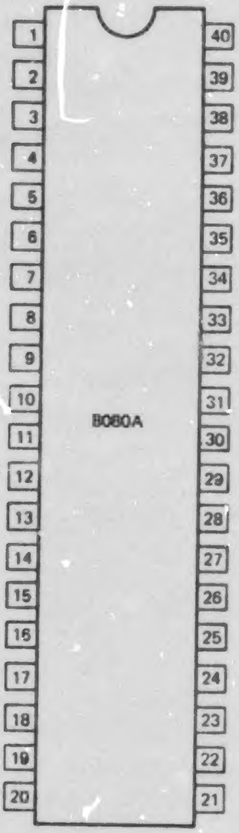
MICROPROCESSORS

UNIT I

ASSIGNMENT SHEET #1 - 8080A Architecture

Label the pins for the 8080A shown in Figure 1. Then describe the function of each pin.

FIGURE 1


8080A
1
2
3
4
5
6
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8
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10
11
12
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14
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16
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20
21
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39
40

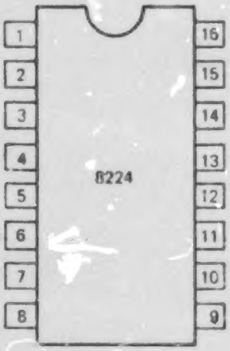
MICROPROCESSORS

UNIT I

ASSIGNMENT SHEET #2 - THE CLOCK GENERATOR (8224) AND SYSTEM CONTROLLER (8228)

1. Label the pins on Figure 1 clock generator (8224) and describe the function of each pin.

FIGURE 1


1
2
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4
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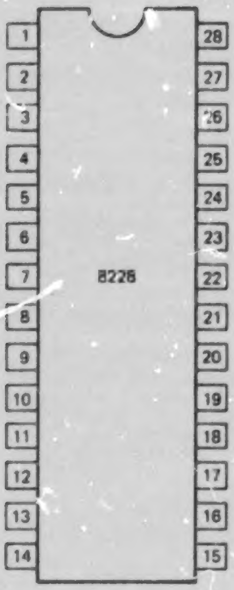
8
8224
16
15
14
13
12
11
10
9

ASSIGNMENT SHEET #2

2. Label the pins on Figure 2, System Controller (8228), and describe the function of each pin.

FIGURE 2


8228
1
2
3
4
5
6
7
8
9
10
11
12
13
14
28
27
26
25
24
23
22
21
20
19
18
17
16
15

MICROPROCESSORS

UNIT I

ASSIGNMENT SHEET #3 - PROBLEMS DEALING WITH THE FUNCTIONING OF THE MICROPROCESSOR

1. How many memory groups are needed in a 32K memory?____________

____

2. Name a use for a bidirectional bus driver____________________

____

3. For a three byte instruction what is the function for each byte:

   a.

   b.

   c.

4. Change the following memory address to its binary equivalent $5FFF_{16}$.

5. When two registers are linked together, how many bit capacity will each linked pair have? ____

____

6. a. If memory is addressed by an instruction the memory address is located in byte ________________________________ and

   ____

   b. When a memory address is the register pair BC the ____________ ______________________ register is the high and ______________ is the low order register.

   c. Memory addressing for the stack pointer uses ____________________ bytes.

ASSIGNMENT SHEET #3

7. The three modes of addressing:

   a. direct ________________________

   b. register ______________________

   c. immediate _____________________

   Each contain how many bytes?

8. Mnemonic codes are useful only to __________________________.

9. Analyze the following program and state what it does:

A Simple Program

Mnemonic	Address$_{16}$	Machine code$_{16}$	Comments
MVI A	0150	3E	Clear A
0	0151	00	Data byte
STA	0152	32	Store A
00	0153	00	Low address byte
02	0154	02	High address byte
ADI	0155	C6	Add to A
20	0156	20	Immediate data
STA	0157	32	Store A
01	0158	01	Low address byte
02	0159	02	High address byte
HLT	015A	76	Stop

10. Where does the MSB go when an RLC instruction is executed?

    ____

    ____

11. JUMP and CALL are two _____________________________ instructions because no stated conditions have to be satisfied in order to perform them.

12. A. The only function the special instruction NOP performs is to

    ____

    B. Does the HLT instruction increment the program counter? _______

    C. PUSH allows the contents of a _________________________ to be placed in the stack.

MICROPROCESSORS

UNIT I

LAB SHEET #1 - USING A MICROPROCESSOR

I. Equipment

A. 1-microcomputer
B. 1-7400
C. 1-LED
D. 1-900 Ω resistor
E. 1-SPST switch
F. Voltmeter
G. Breadboard
H. Hook-up wire

II. Procedures

A. Record the range of memory addresses for your computer in hex and decimal.

__________________________ __________________________

B. Record the I/O port addresses and indicate the purpose of each port.

________________________ ________________ ______________

C. Record the procedures for changing and inspecting the contents of a memory cell.

____

____

____

____

D. Explain how the value of a register may be examined or replaced and how a program is executed.

____

____

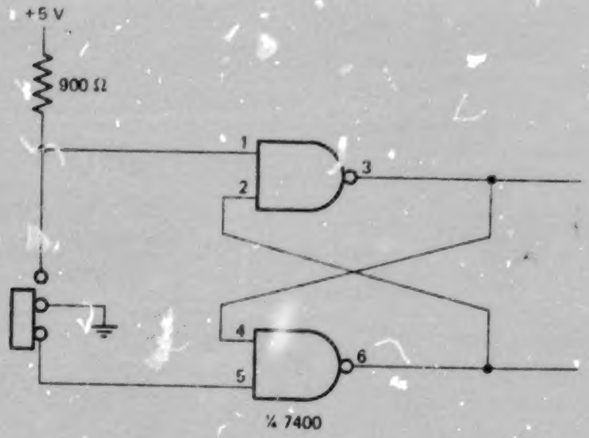
____

____

LAB SHEET #1

E. Connect the circuit shown in Figure 1.

FIGURE 1



F. Turn on the power.

G. Connect the LED to each output and record the voltage level at pin 3 (______________) and pin 6 (____________).

H. Close the switch and repeat the readings for pin 3 (_________) and pin 6 (__________).

I. How could this pulser be used to produce sequals that swing between high and low levels.

J. Turn off your power.

K. Have your instructor observe your results.

L. Put up your equipment.

MICROPROCESSORS

UNIT I

LAB SHEET #2 - USING A MICROCOMPUTER FOR ADDITION AND SUBTRACTION

I. Equipment: Microcomputer

II. Procedure

A. Enter the program

Mnemonic	Address	Instruction
LHLD	0000	2A
21	0001	21
00	0002	00
LDA	0003	3A
20	0004	20
00	0005	00
ADD M	0006	86
OUT 0	0007	D3
	0008	00
HLT	0009	76

B. Values to enter in 0020_{16} and 0021_{16}.

Location 0020_{16}	Location 0021_{16}	Sum
14	3B	
56	21	
82	45	
F2	E4	

C. Run the program and record the results obtained at the I/O pin for each set of value.

______________(4F)

______________(77)

______________(C7)

______________(D6)

D. Change cell 0006 to a subtraction instruction (96).

LAB SHEET #2

E. Load the following sets of valvues in 2020_{16} and 0021_{16}.

Location 0020_{16}	Location 0021_{16}	Difference
41	3A	
3A	2D	
28	85	
EA	FB	

F. Run the program and record the results obtained at the I/O port.

______________(7)

______________(D)

______________(A3)

______________(EF)

G. Check your results by manual adding and subtracting the sets of value in Steps C and F.

H. Show your results to your instructor.

I. Put your equipment away.

MICROPROCESSORS

UNIT I

LAB SHEET #3 - USING LOGICAL INSTRUCTIONS

I. Equipment: Microcomputer

II. Procedure

A. Load the following program:

Instruction	Address	Machine Code
LDA 0050	0000	3A
	0001	50
	0002	00
STC	0003	37
LX1 H, 0051	0004	21
	0005	51
	0006	00
ADD M	0007	86
INR L	0008	2C
MOV M,A	0009	77
HLT	000A	76

B. Load the following data set:

Data Set	0050	0051
1	37	46
2	2E	A3
3	89	BC

C. Run the program for each set of data and record your results.

_______________(7D)

_______________(D1)

_______________(45)

D. Change the instruction in 0007$_{16}$ to 8E.

E. Run the program using the following data:

Data Set	0050	0051
4	37	46
5	74	62

LAB SHEET #3

F. Record the results

__________(7D)

__________(D6)

G. Change 0007_{16} to 9E and load the following data:

Data Set	0050	0051
9	7D	66
10	D2	C8

H. Record your results

____________(17)

____________(A)

I. Change 0007_{16} to A6 and load the following data:

Data Set	0050	0051
11	AA	96
12	21	E7
13	A5	5A

J. Record your results

______________(82)

______________(21)

______________(0)

K. Change 0007_{16} to B6 and load the following data:

Data Set	0050	0051
14	73	4C
15	F7	30

L. Record your results

______________(7F)

______________(F7)

LAB SHEET #3

M. Change 0007_{16} to AE and load the following data:

Data Set	0050	0051
16	A5	5A
17	73	4C
18	17	17

N. Record your results.

_______________(FF)

_______________(3F)

_______________(0)

O. Show your results to your instructor.

P. Put up your equipment.

MICROPROCESSORS
UNIT I
TEST

NAME____ SCORE________________

1. Match terms associated with microprocessors to their correct definitions. Write the correct number in the blank.

_____ a. A command made up of 3 bytes that gives a specific address to operate.

_____ b. The memory organization for a computer system.

_____ c. Timing cycles during which operations occur.

_____ d. Lines that control where data is coming from and going to.

_____ e. Two-way lines connecting components.

_____ f. The structure of a computer's internal parts and the structure used to move command and data.

_____ g. Computer commands that can be categorized as data transfer, arithmetic, logical branching, input/output.

_____ h. Storage device that stores specific data.

_____ i. Signals necessary to coordinate different internal functions.

_____ j. Lines used to move information.

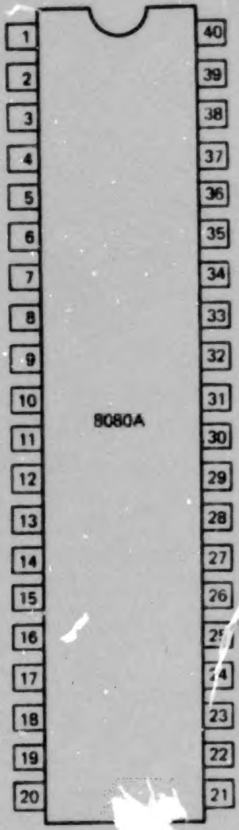
_____ k. Lines that supply commands and timing to move data.

_____ l. Two byte command that has the quantity to be operated on following the op code byte.

1. Bus
2. Control bus
3. Register
4. Memory map
5. Direct addressing
6. Address bus
7. Timing signal
8. Machine cycles
9. Instruction
10. Immediate addressing
11. Architecture
12. Data bus

TEST

2. Label each pin on the 8080A and give its purpose.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24
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22
21
8080A

3. Explain the function of each part of the clock generator (8224).

8224 Signals

Name	Purpose	Type
OSC		
RDYIN		
READY		
RESET		
$\overline{\text{RESIN}}$		
$\overline{\text{STSTB}}$		
SYNC		
XTAL1, XTAL2, TANK		
Φ1, Φ2		
Φ2 (TTL)		

TEST

4. Explain how the system controller (8228) works in conjunction with the 8080A.

System Control Bus Signals

Inputs	System control bus output
MEMR (D7) AND DBIN	
OUT (D4) AND WR	
INP (D6) AND DBIN	
OUT (D4) AND $\overline{\text{WR}}$	
INTA (D0)	

5. Describe how memory addresses are determined in the 8080A.

6. Give a use for bidirectional bus drives.

TEST

7. List the function of each byte in an 8080A instruction.

8. Change the following 8080A memory addresses to binary numbers.

a. 2000_{16} ____

b $7FFC_{16}$ ____

9. List the addresses for the single and linked registers.

Single	Linked
B	BC
C	DE
D	HL
E	PSW/A
H	
L	
A	

10. List three types of memory addressing:

a.

b.

c.

TEST

11. State how the number of I/O devices are determined.

12. Name three addressing modes:

a.

b.

c.

13. Explain how mnemonic codes relate to op codes.

14. Explain what the following move instructions mean:

a. MOV D, M ____

____

b. STA ____

____

TEST

15. Describe how the following arithmetic instructions work.

    a. INRS ____

    ____

    ____

    b. SUBS ____

    ____

    ____

16. Explain how the RAR rotate instructions works.

17. Indicate whether the following instructions are conditional (C) or unconditional (U). Place a I pr C in the blank.

    a. JUMP ____________

    b. CALL ____________

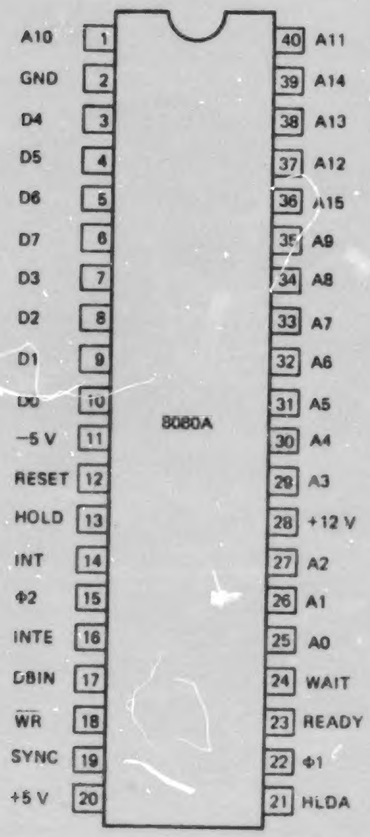
    c. JZ ____________

18. Describe the function of the special instruction POP.

19. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

MICROPROCESSORS
UNIT I

ASSIGNMENT SHEET #1 - ANSWERS

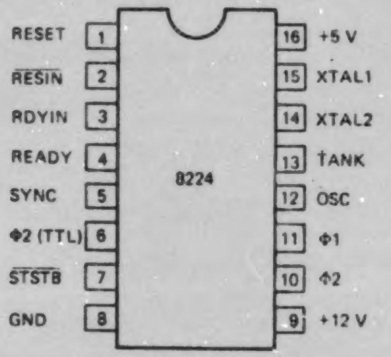

8080A
A10 1
GND 2
D4 3
D5 4
D6 5
D7 6
D3 7
D2 8
D1 9
D0 10
−5 V 11
RESET 12
HOLD 13
INT 14
Φ2 15
INTE 16
DBIN 17
$\overline{WR}$ 18
SYNC 19
+5 V 20
40 A11
39 A14
38 A13
37 A12
36 A15
35 A9
34 A8
33 A7
32 A6
31 A5
30 A4
29 A3
28 +12 V
27 A2
26 A1
25 A0
24 WAIT
23 READY
22 Φ1
21 HLDA

MICROPROCESSORS

UNIT I

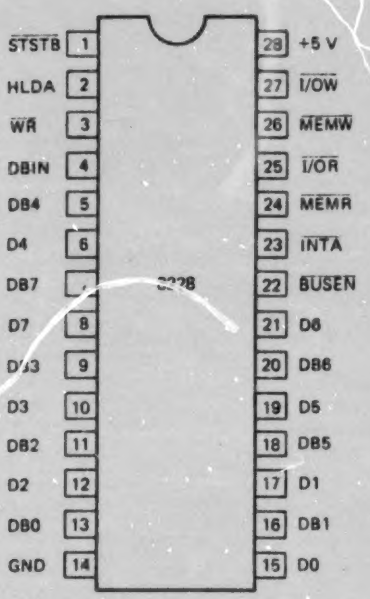
ASSIGNMENT SHEET #2 - ANSWERS

1.


RESET 1
RESIN 2
RDYIN 3
READY 4
SYNC 5
Φ2 (TTL) 6
STSTB 7
GND 8
16 +5 V
15 XTAL1
14 XTAL2
13 TANK
12 OSC
11 Φ1
10 Φ2
9 +12 V
8224

Refer to item III, Information Sheet, for answers

2.


STSTB 1
HLDA 2
WR 3
DBIN 4
DB4 5
D4 6
DB7
D7 8
DB3 9
D3 10
DB2 11
D2 12
DB0 13
GND 14
28 +5 V
27 I/OW
26 MEMW
25 I/OR
24 MEMR
23 INTA
22 BUSEN
21 D6
20 DB6
19 D5
18 DB5
17 D1
16 DB1
15 D0

Refer to Item IV, Information Sheet, for answers

MICROPROCESSORS

UNIT I

ASSIGNMENT SHEET #3 - ANSWERS

1. 32 0000_{16} - $7FFF_{16}$

2. Used to drive loads for the MPU.

3. a. Command
   b. Operand or device
   c. Second byte of two byte address or data byte

4. $0101\ 1111\ 1111\ 1111_2$

5. 16

6. a. 2 & 3
   b. B, C
   c. 2

7. a. 3
   b. 1
   c. 2

8. Programmer

9. Clear the accumulator
   Clear memory 0200_{16}
   Add 20_{16} to accumulator
   Store accumulator to 0201_{16}
   Stop

10. MSB to LSB

11. Unconditional

12. a. Increment the program counter
    b. No
    c. Register pair

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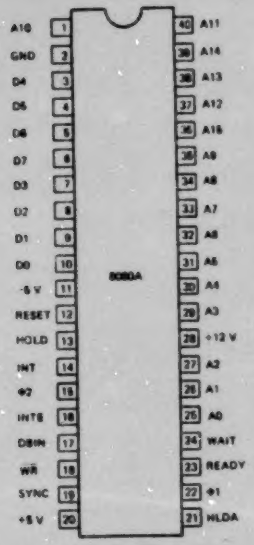
MICROPRESSORS

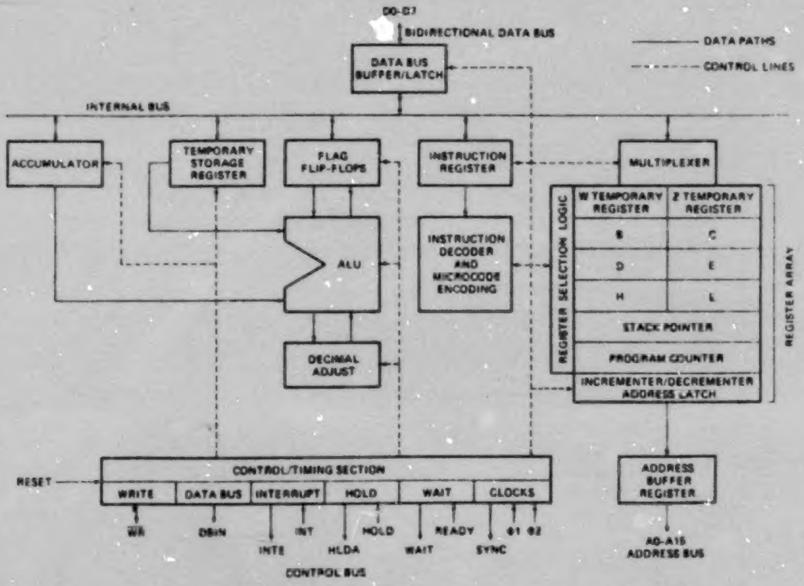
UNIT I

TEST ANSWERS

1. a. 5
   b. 4
   c. 8
   d. 6
   e. 1
   f. 11
   g. 9
   h. 3
   h. 3
   i. 7
   j. 12
   k. 2
   l. 10

2.


8080A
A10 1
GND 2
D4 3
D5 4
D6 5
D7 6
D3 7
D2 8
D1 9
D0 10
-5 V 11
RESET 12
HOLD 13
INT 14
Φ2 15
INTE 16
DBIN 17
WR 18
SYNC 19
+5 V 20
40 A11
39 A14
38 A13
37 A12
36 A15
35 A9
34 A8
33 A7
32 A6
31 A5
30 A4
29 A3
28 +12 V
27 A2
26 A1
25 A0
24 WAIT
23 READY
22 Φ1
21 HLDA


D0-D7
BIDIRECTIONAL DATA BUS
DATA PATHS
CONTROL LINES
DATA BUS BUFFER/LATCH
INTERNAL BUS
ACCUMULATOR
TEMPORARY STORAGE REGISTER
FLAG FLIP-FLOPS
INSTRUCTION REGISTER
MULTIPLEXER
ALU
INSTRUCTION DECODER AND MICROCODE ENCODING
REGISTER SELECTION LOGIC
W TEMPORARY REGISTER
Z TEMPORARY REGISTER
B
C
D
E
H
L
STACK POINTER
PROGRAM COUNTER
INCREMENTER/DECREMENTER ADDRESS LATCH
REGISTER ARRAY
DECIMAL ADJUST
RESET
CONTROL/TIMING SECTION
WRITE
DATA BUS
INTERRUPT
HOLD
WAIT
CLOCKS
WR
DBIN
INTE
INT
HLDA
HOLD
WAIT
READY
SYNC
Φ1 Φ2
CONTROL BUS
ADDRESS BUFFER REGISTER
A0-A15 ADDRESS BUS

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TEST ANSWERS

3.

8224 Signals

Name	Purpose	Type
OSC	Crystal oscillator waveform	Output
RDYIN	Ready signal	Input
READY	Control signal to 8080A	Output
RESET	Control signal to 8080A	Output
$\overline{\text{RESIN}}$	Reset signal	Input
$\overline{\text{STSTB}}$	Sync signal	Output
SYNC	Control signal	Input
XTAL1, XTAL2, TANK	External crystal connections	Input
$\Phi 1$, $\Phi 2$	Clock signals	Output
$\Phi 2$ (TTL)	TTL-compatible clock	Output

4.

System Control Bus Signals

Inputs	System control bus output
MEMR (D7) AND DBIN	$\overline{\text{MEMR}}$
OUT (D4) AND WR	$\overline{\text{MEMW}}$
INP (D6) AND DBIN	$\overline{\text{I/OR}}$
OUT (D4) AND $\overline{\text{WR}}$	$\overline{\text{I/OW}}$
INTA (D0)	$\overline{\text{INTA}}$

TEST ANSWERS

5. a. There are 16 address lines therefore $2^{16} = 65536$ addressable addresses.

   b. A memory decoder (8025) selects a particular 1K block (A10-A14).

   c. A0-A9 on the address bus then further selects one of its 1K cells.

6. Used to supplement MPC loads.

7. a. First byte is the op code.

   b. Second byte is the data to be operated on or the address of the data to be operated on.

   c. Third byte is the data to be operated on or the record byte of two byte address.

8. $2000_{10} = 0010000000000000_2$

   $7FF0_{16}$ = 0111 1111 1111 0000

9.

Single		Linked	
B	0	BC	B or 0
C	1	DE	D or 1
D	2	HL	H or 2
E	3	PSW/H	3
H	4		
L	5		
A	7		

10. 3 byte, 1 for op code, 2 for address
    2 byte, register pair address
    2 byte, stack pointer address

11. The I/O address has 8 bits therefore (2") $2^8 = 256$ devices

12. a. Direct addressing
    b. Register addressing
    c. Immediate addressing

13. Mneumonic codes are usually 3 letter codes that stand for a hexadecimal machine language op code.

14. a. MOV D, M. Put the contents of memory location M into register D.

    b. STA. Put the contents of the accumulator in memory location specified by the byte following the STA instruction.

TEST ANSWERS

15. INRS. The contents of the source register S is incremented by one.

    SUBS. The contents of the accumulator are subtracted by the contents of register S and the result is left in the accumulator.

16. The contents of the accumulator are rotated to the right one place. The carry moves to the MSB and the LSB bit moves to the MSB.

17. a. U
    b. U
    c. C

18. The contents of the address at the top of the stack are placed in the designate register pair.

MICROPROCESSOR AND INTERFACING

UNIT II

INPUT/OUTPUT

INPUT/OUTPUT

UNIT II

OBJECTIVE

After completing this unit, the student should be able to describe how I/O controllers and I/O devices function together. The student should also be able to explain how the DMA controllers and Serial I/O Receivers/Transmitters function with the 8080A Microprocessor. This knowledge will be shown by completing lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with Input/Output to their correct definition.
2. List the commonly used input/output codes.
3. Name three methods of error detection.
4. List six devices used as input/output devices.
5. Describe how the accumulator inputs and outputs data.
6. Describe the operation of an I/O port.
7. List advantages of memory mapped I/O.
8. Describe an interrupt sequence.
9. Explain how a Direct Memory Access Controller may be used as an I/O part or a memory mapped I/O.
10. Discuss the port features of Synchronous and Asnychronous Receiver/Transmitters.
11. Demonstrate the ability to
    A. Use I/O Hex Display
    B. Use I/O Hex Display with a microcomputer

INPUT/OUTPUT

UNIT II

SUGGESTED ACTIVITIES

I. Instructor

  A. Provide students with procedure sheet.

  B. Provide students with information and lab sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information and lab sheets.

  F. Use another family of microprocessors to demonstrate similarities to 8080 input/output.

  G. Show students how DMA can be used to control I/O.

  H. Relate advantages of synchronous and asnychronous I/O.

  I. Assist students in wiring and troubleshooting their microcomputer.

  J. Give test.

II. Student

  A. Read objective sheet.

  B. Study information sheet.

  C. Complete lab sheets.

  D. Take test.

INPUT/OUTPUT

UNIT II

INSTRUCTIONAL MATERIAL

I. Included in this unit:

   A. Objective sheet.

   B. Information sheets.

   C. Lab sheets.

   D. Test.

   E. Answers to test.

II. References

A. Pasahow, Edward J., Microprocessors and Microcomputer, New York, New York, McGraw-Hill Book Co., 1981.

B. Camp, Smay, Triska, Microprocessor Systems Engineering, Beaverton, Oregon, Matrix Publishers, 1979.

C. Rony, Peter R., Introductory Experiments in Digital Electronic and 8080A Microcomputer Programming and Interfacing VI, Indianapolis, Indiana, Howard W. Sams & Co.

D. Pasahow, Edward J., Microcomputer Interfacing, New York, New York, McGraw-Hill Book Co., 1981.

E. Staugaard, Andrew C., Microprocessor Interfacing, Benton Harbor, Michigan, Heath Co., 1982.

F. Hall, Douglas V. and Marybelle B., Experiments in Microprocessors and Digital System, New York, New York, McGraw-Hill Book Co., 1983.

G. Brey, Barry B., Microprocessor Hardware Interfacing and Applications, Columbus, Ohio, Charles E. Merrill Publishing Co., 1984.

INPUT/OUTPUT

UNIT II

PROCEDURE SHEET

______1.	Study	Chapter 3, 4, and 5, Microcomputer Interfacing, Pasahow.
______2.	Study	Information Sheets.
______3.	Do	Lab Sheet #1 - I/O Using Hexidecimal Display
______4.	Write	An informal lab report Lab Sheet #1 - I/O Using Hexidecimal Display.
______5.	Do	Lab Sheets #2 - Using I/O Hex Display with a microcomputer.
______6.	Write	An Informal lab report for Lab Sheets #2 - I/O Hex Display with a Microcomputer.
______7.	Stop	Have your instructor evaluate the results of Labs Sheets #1 and #2. If the instructor is satisfied with your results continue on to step 8. Otherwise consults with your instructor.
______8.	Turn-in	All lab reports.
______9.	Review	Chapter 3, 4, and 5 Microcomputer Interfacing, Information and Lab Sheets.
_____10.	Complete	Unit Test - Input/Output.

INPUT/OUTPUT

UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Codes - codes such as ASCII and BCD are used by peripheral equipment and translated to binary's and 0's to be used by internal IC's.

   B. Error detection - methods such as parity, check series and CRC are used to insure correction data transmission and error detection.

   C. Peripheral equipment - equipment such as printer, keyboards, CRT terminals, modems, floppy disk drives, and magnetic tape recorders.

   D. Accumulator I/O - data can be transferred in or out of the microprocessor through the accumulator.

   E. Interfacing - a device that connects a microprocessor with I/O equipment and makes necessary changes to make both compatible.

   F. Buffering - a temporary storage used in I/O operation to provide signal stability and increase operational speed.

   G. I/O parts - a buffer made up of flip-flops for latches.

   H. Memory mapped I/O - method in I/O operations where I/O devices are given memory addresses.

   I. Interrupt - a signal that causes the microprocessor to stop normal processing and begin an interrupt sequence.

   J. Interrupt instruction - the 8080A has two sets of instruction to handle interrupts-control and vectoring.

   K. Priority interrupt control circuit - the 8080A can use up to 8 - 8259 (PICU) to provide 64 levels of interrupt activity.

   L. Direct memory access - a controller that prevents a decrease in processing speed by performing high speed transfers between memory and I/O devices.

   M. Parallel data exchange - I/O data is transferred in groups of bits.

   N. Serial data exchange - I/O data is transferred one bit at a time.

   O. Band rate - rate of transferring data, i.e., 300 bits/sec or 1200 bits/sec. bits/sec = band

INFORMATION SHEET

3. Code - mostly ASCII

4. Type
    a. Impact - slower
    b. Non-impact - ink-jet, fast

B. Keyboard - input

1. Usually a group of keys
2. Each key is sensed depressed through row and column lines
3. Good use of debouncing logic

C. CRT - output

1. Alphanumeric display
2. Graphics display

D. Modems

1. Convert digital data to analog data
2. Used to transmit data over telephone lines
3. A one can be represented by 1,200 by tone which a zero can be represented by a 2,200 by tone
4. Methods of transmission

    a. Simplex - one direction only
    b. Half-duplex - two-way but one at a time
    c. Full-duplex - two-way both at the same time

E. Floppy disk drive

1. Plastic disk of varying sizes
2. Densities
    a. Standard 125K/side
    b. Double 250K/side
    c. Double track/double 481K/side
3. Disk
    a. Tracks divided into sectors
    b. Sectors divided into ID field and DATA field

F. Magnetic tape recorder

1. Medium is coated plastic tape capable of storing 1's or 0's
2. Recording rates
    a. 800 bits/in
    b. 1,200 bits/in
3. Clock rate is recorded on the tape to insure reliability when using other machines.

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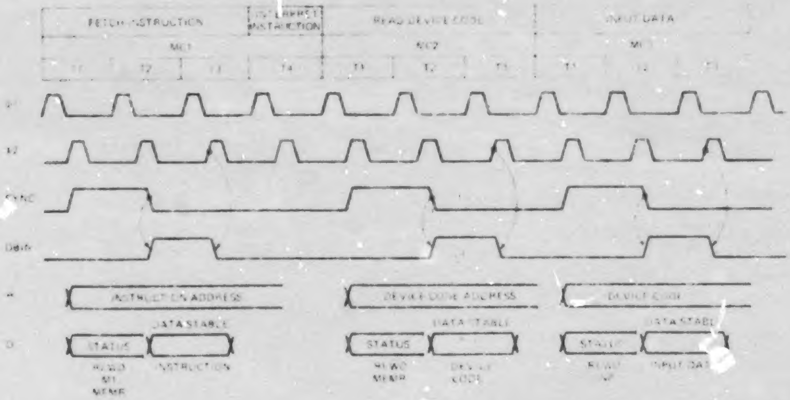
V. Accumulator I/O

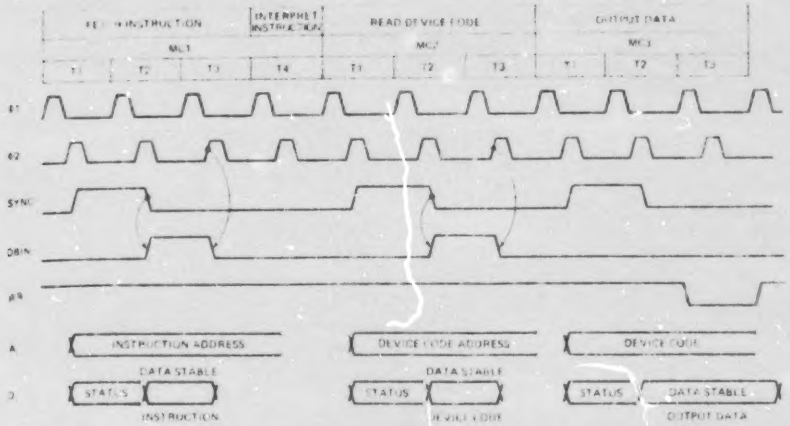
A. Input

1. The input instruction requires 3 machine cycles.
2. MC 1 - the instruction is fetched and interpreted.
3. MC 2 - the device code is obtained from memory.
4. MC 3 - data is transferred.


FETCH INSTRUCTION
INTERPRET INSTRUCTION
READ DEVICE CODE
INPUT DATA
MC1
MC2
MC3
T1
T2
T3
T4
T1
T2
T3
T1
T2
T3
SYNC
DBIN
INSTRUCTION ADDRESS
DEVICE CODE ADDRESS
DEVICE CODE
DATA STABLE
DATA STABLE
DATA STABLE
STATUS
STATUS
STATUS
READ M1 MEMR
INSTRUCTION
READ MEMR
DEVICE CODE
READ INP
INPUT DATA

B. Output

1. The output instruction requires 3 machine cycles.
2. MC 1 - instruction is fetched and interpreted.
3. MC 2 - the device code is read.
4. MC 3 - data is set out.


FETCH INSTRUCTION
INTERPRET INSTRUCTION
READ DEVICE CODE
OUTPUT DATA
MC1
MC2
MC3
T1
T2
T3
T4
T1
T2
T3
T1
T2
T3
φ1
φ2
SYNC
DBIN
A
INSTRUCTION ADDRESS
DEVICE CODE ADDRESS
DEVICE CODE
DATA STABLE
DATA STABLE
D
STATUS
STATUS
STATUS
DATA STABLE
INSTRUCTION
DEVICE CODE
OUTPUT DATA

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INFORMATION SHEET

VI. I/O devices

A. Interfacing microprocessors with I/O equipment

1. Distance must be compensated for - 8228 system controller will work.
2. Fan out must be considered - the 7415 logic series will handle.

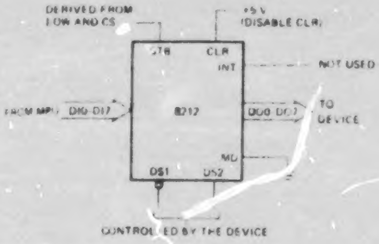
B. Address selection - use a special NAND gate that will accept only one code or address to select a device.

C. Buffering

1. Can be accomplished using the 8095.
2. Only allows data to 8080A data bus if properly coded ($\overline{CS}$ and $\overline{I/OR}$)

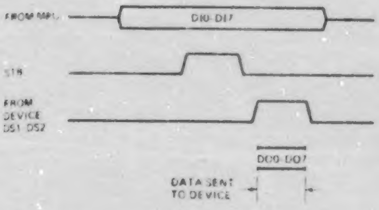
D. I/O port - 8212 is 8 bit latch used for I/O.

EXAMPLE: Input wiring and timing



DERIVED FROM
I/OW AND CS
+5 V
(DISABLE CLR)
STB
CLR
INT
NOT USED
FROM MPU
DI0-DI7
8212
DO0-DO7
TO
DEVICE
MD
DS1
DS2
CONTROLLED BY THE DEVICE

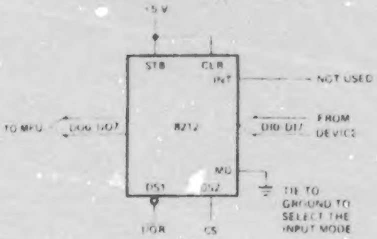
(a)



FROM MPU
DI0-DI7
STB
FROM
DEVICE
DS1 DS2
DO0-DO7
DATA SENT
TO DEVICE

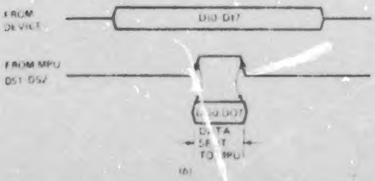
(b)

EXAMPLE: Output wiring and timing



+5 V
STB
CLR
INT
NOT USED
TO MPU
DO0-DO7
8212
DI0-DI7
FROM
DEVICE
MD
DS1
DS2
TIE TO
GROUND TO
SELECT THE
INPUT MODE
I/OR
CS

(a)



FROM
DEVICE
DI0-DI7
FROM MPU
DS1 DS2
DO0-DO7
DATA
SENT
TO MPU

(b)

INFORMATION SHEET

VII. Memory mapped I/O

A. Memory instructions can be used with these devices.

B. Disadvantages

1. Need to decode 16 bit address
2. Memory is sacrified for device addresses

C. Advantage

1. Can use any of general purpose registers.
2. Faster than accumulator
3. More than 256 device codes
4. Data can be directly used

VIII. Interrupt

A. Types

1. Single - all devices are ORed to the MPU. MPU then looks at each for request.
2. Multiple - MPU knows which device has requested service.
3. Vectored - most sophisticated and requires additional hardware.

B. Types of instruction

1. Control
    a. Enable - allows interrupts
    b. Reset - disallows interrupts

2. Vectoring
    a. When MPU receives the RST instruction from a device requesting service, the MPU enters a specific service routine.

C. Example procedure

1. Complete current instruction
2. Clears interrupt flip-flop
3. Take service program address from data lines
4. Saving next program address
5. Jump to vector address
6. Begin processing program
7. Either halt or pull last regular program address to stack.

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IX. Interrupt control unit

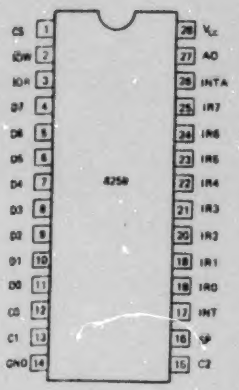
A. 8259 IC is 28 pin NMOS DIP (8228 is required).

1. Can be used to control 8 interrupts
2. Or can be slaved to control 64 levels of interrupt
3. Pin assignments and functions in Figure 1.

FIGURE 1

8259 Signal Description

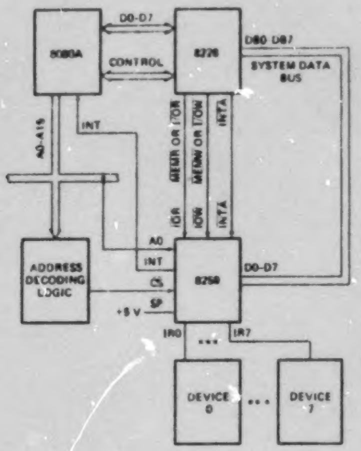
Name	Purpose	Type
$\overline{\text{CS}}$	Device select	Input
A0	I/O port identification	Input
D0-D7	Data bus	Bidirectional, three state
$\overline{\text{IOR}}$	Read control	Input
$\overline{\text{IOW}}$	Write control	Input
IR0-IR7	Interrupt requests from external devices	Input
INT	Interrupt request to 8080A	Output
$\overline{\text{INTA}}$	Interrupt acknowledge	Input
$\overline{\text{SP}}$	Master/slave identification (high for master, low for slaves)	Input
C0-C2	Cascade signals to select slaves in multiple 8259 systems	Output (from master)/input (to slaves)



8259
CS 1
IOW 2
IOR 3
D7 4
D6 5
D5 6
D4 7
D3 8
D2 9
D1 10
D0 11
C0 12
C1 13
GND 14
28 Vcc
27 A0
26 INTA
25 IR7
24 IR6
23 IR5
22 IR4
21 IR3
20 IR2
19 IR1
18 IR0
17 INT
16 SP
15 C2

B. Figure 2 shows a diagram of single 8259 system.

FIGURE 2



8080A
D0-D7
CONTROL
8228
DB0-DB7
SYSTEM DATA BUS
A0-A15
INT
MEMR OR I/OR
MEMW OR I/OW
INTA
IOR
IOW
INTA
A0
INT
CS
SP
+5 V
ADDRESS DECODING LOGIC
8259
D0-D7
IR0
IR7
DEVICE 0
DEVICE 7

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C. Programming

1. Interrupt priorities established by connecting to pins IR0 - IR7. 0 has highest priority.

2. Rotating priorities allows all priorities to have a chance to be served but in order (0 then 1 then 2 etc.)

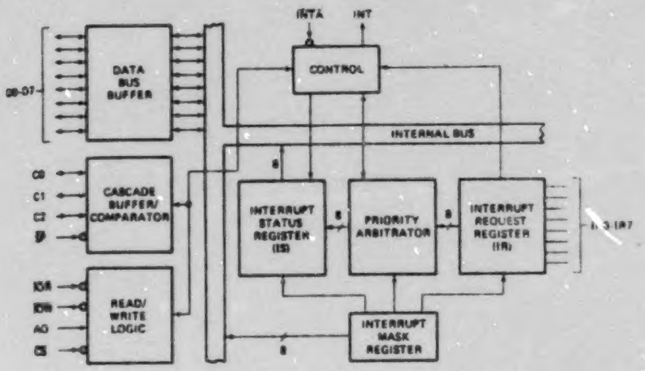
3. Polled mode has the MPU checking each interrupt. No interrupts are generated. The structure of the polled word determines the level of interrupt.

4. Mark mode can be superinposed on either priority or rotating mode to disable them.

5. Special mark mode allows interrupts from a lower priority.

D. Architecture

FIGURE 3


INTA
INT
D0-D7
DATA BUS BUFFER
CONTROL
INTERNAL BUS
C0
C1
C2
SP
CASCADE BUFFER/ COMPARATOR
8
INTERRUPT STATUS REGISTER (IS)
PRIORITY ARBITRATOR
INTERRUPT REQUEST REGISTER (IR)
IR0-IR7
IOR
IOW
A0
CS
READ/ WRITE LOGIC
INTERRUPT MASK REGISTER

1. Data bus buffer holds data enroute from internal to data bus.
2. Cascade comparator recognizes a slave write address.
3. Read/write logic informs the control unit of the direction of flow.

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4. Interrupt request and interrupt status maintain logic priority.

5. Interrupt mark changes priorities as programmed.

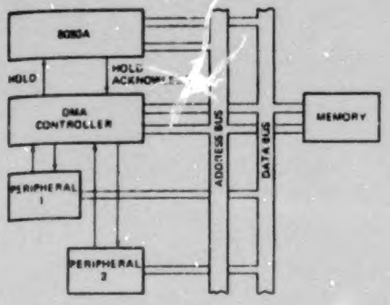
6. Control unit initiates the interrupt signal.

X. Direct memory access

A. The DMA has controls to mimic the MPU in controlling reading and writing memory.

B. Simplified DMA diagram in Figure 4.

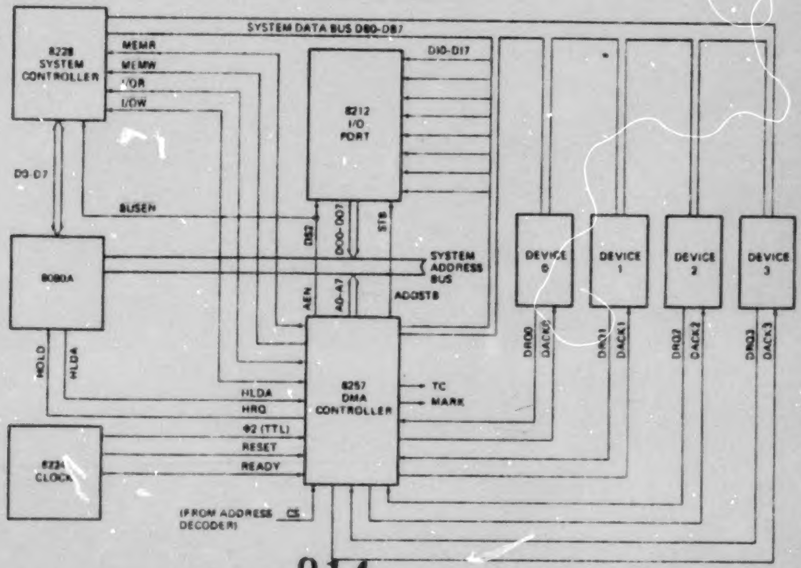
FIGURE 4


8080A
HOLD
HOLD ACKNOWLEDGE
DMA CONTROLLER
ADDRESS BUS
DATA BUS
MEMORY
PERIPHERAL 1
PERIPHERAL 2

1. MPU and DMA indicate which is presently directing the system buses by means of the HOLD and HLDA.

2. Once DMA gains access data flows under control of the DMA.

C. 8080A DMA system


8228 SYSTEM CONTROLLER
SYSTEM DATA BUS DB0-DB7
MEMR
MEMW
I/OR
I/OW
8212 I/O PORT
DI0-DI7
D0-D7
BUSEN
DS2
DO0-DO7
STB
8080A
SYSTEM ADDRESS BUS
AEN
A0-A7
ADSTB
DEVICE 0
DEVICE 1
DEVICE 2
DEVICE 3
DRQ0
DACK0
DRQ1
DACK1
DRQ2
DACK2
DRQ3
DACK3
HOLD
HLDA
HLDA
HRQ
Φ2 (TTL)
RESET
READY
8257 DMA CONTROLLER
TC
MARK
8224 CLOCK
(FROM ADDRESS DECODER)
CS

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D. DMA process to transfer data

1. Starting address, number of words, and direction is loaded into register.

2. As each word is transferred the address register increments.

3. The count register decrements.

E. Priority accessing

1. The DMA acknowledges a request by sending $\overline{\text{DACH}}$ to the register.
2. Priority is set in programming.
3. In the fixed priority mode the requests are honored as requests.
4. In the rotating mode requests are honored in order.

F. DMA options

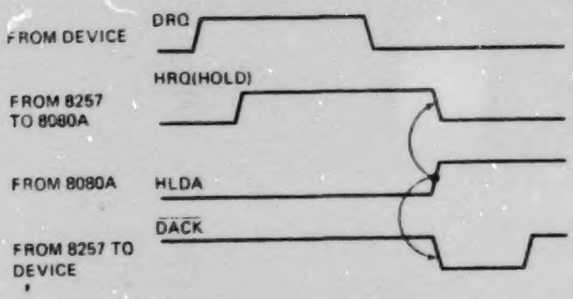
1. One byte at a time then reset/set DRQ
2. A block at a time DRQ remains set until all bytes have been transferred.
3. The setting of bits 14 and 15 of the control word determines the direction of flow.

Directional Bits

Bit numbers		8257 Acting as an I/O port	8257 Acting as a memory-mapped device
15	**14**		
0	0	Verify cycle	Verify cycle
0	1	Write cycle	Read cycle
1	0	Read cycle	Write cycle
1	1	Not used	Not used

G. Timing is shown in Figure 5

FIGURE 5

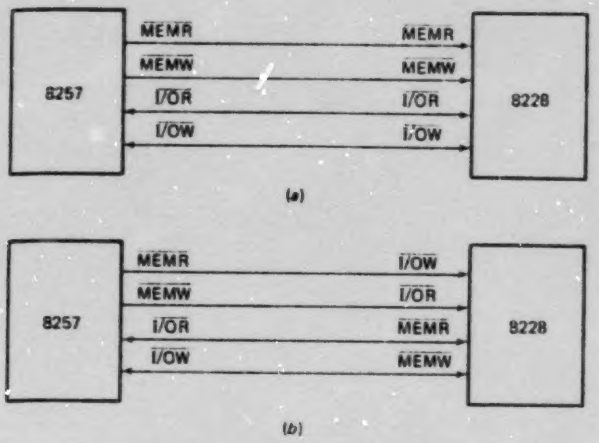


INFORMATION SHEET

H. Programming by the programmers

1. Control appears as one of two choices:
   a. I/O port
   b. Memory mapped (see Figure 6)

FIGURE 6



2. Load the address register.

3. Load the count load register--the command register with the command for the next DMA operation.

X. Serial receivers and transmitters

A. Functions of receiver/transmitter

1. Parallel data is received from MPU.
2. Data is held in a register until time to move it to transmit buffer.
3. Data is transmitted serially out.
4. Serial data comes in to the receive buffer when the bit accumulates until there are 8.
5. The 8 bits are forwarded in a parallel mode through the receive holding buffer to the data register.
6. Through MPU control data is moved on into the MPU.

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B. Synchronization between the input units and the MPU, which both have clocks, is accomplished before data is transferred.

C. Handshaking between receiver and transmitter is accomplished by several codes.

Handshaking Protocol with a Telephone

Source	ASCII control character	Meaning
Transmitter	ENQ	Are you ready to receive?
Receiver	DC0	Yes (receiver must have been set up in advance).
Transmitter	STX	Start of text.
	DATA BLOCK	
	ETB	End of block.
	CRC CRC	Cyclic redundancy check sent twice.
Receiver		Receiver has checked data with CRC. No errors have been detected.
		and
	DC1	An even number of data blocks has been received so far.
		or
	DC0	An odd number of data blocks has been received so far.
Transmitter	STX Data block ETB CRC CRC	Repeat until all data has been sent.
Transmitter	EOT	End of transmission.

D. Asynchronous protocol allows sending only when there is data to transmit.

E. Modem control signals have been established.

Control Signals

Step	Signal	Level	Set by	Meaning
1	$\overline{DTR}$	Low	Data terminal	Data terminal ready.
2	$\overline{DSR}$	Low	Modem	Data set (modem) ready to receive. Transmission cannot begin until this signal goes low.
3	...	...	...	Text is prepared
4	$\overline{RTS}$	Low	Data terminal	Request to send. The data terminal is ready to send to the modem. ($\overline{DSR}$ and $\overline{DTR}$ must remain low.)
5	$\overline{CTS}$	Low	Modem	Clear to send. The modem lowers this signal 2 µs after receipt of $\overline{RST}$, if ready to receive.
6	...	...	Data terminal	Data is transmitted.

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F. Synchronous data transmission

1. Two basic types

    a. Synchronous data link control (SDIC). IBM uses this in its communication.
    b. High-level data link control (HDLC)

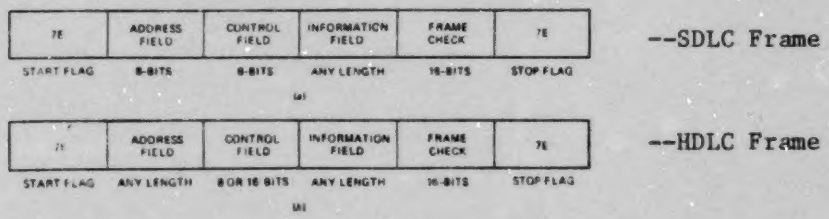
2. Primary can talk to secondary

3. Address field in the message indicates which secondary is to receive the message.

4. Each receiver periodically acknowledges messages have been received correctly.

5. Messages have a format (see Fig 7).

FIGURE 7


7E
ADDRESS FIELD
CONTROL FIELD
INFORMATION FIELD
FRAME CHECK
7E
START FLAG
8-BITS
8-BITS
ANY LENGTH
16-BITS
STOP FLAG
(a)
--SDLC Frame
7E
ADDRESS FIELD
CONTROL FIELD
INFORMATION FIELD
FRAME CHECK
7E
START FLAG
ANY LENGTH
8 OR 16 BITS
ANY LENGTH
16-BITS
STOP FLAG
(b)
--HDLC Frame

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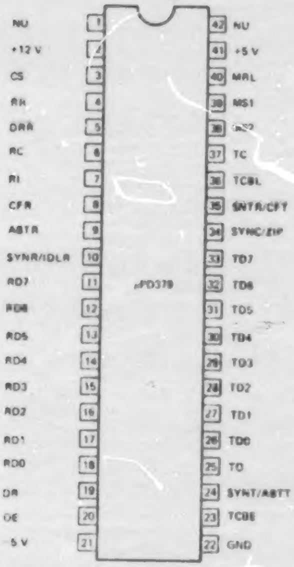
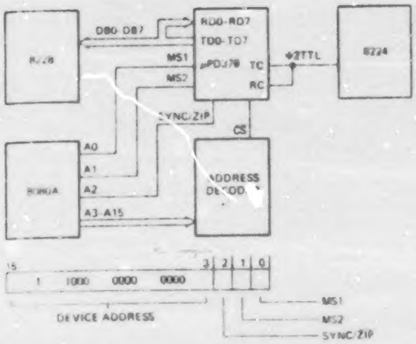
G. NEC MPD379 Synchronous Receiver/Transmitter


NU
+12 V
CS
RR
DRR
RC
RI
CFR
ABTR
SYNR/IDLR
RD7
RD6
RD5
RD4
RD3
RD2
RD1
RD0
DR
OE
-5 V
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
μPD379
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
NU
+5 V
MRL
MS1
MS2
TC
TCBL
SNTR/CFT
SYNC/ZIP
TD7
TD6
TD5
TD4
TD3
TD2
TD1
TD0
TO
SYNT/ABTT
TCBE
GND

μPD379 Signals

Signal	Purpose		Type
	Standard synchronous	SDLC	
RD0-RD7	Data bus	Data bus	Output
TD0-TD7	Data bus	Data bus	Input
$\overline{RR}$	Receive logic select	Receive logic select	Input
$\overline{CS}$	Device select	Device select	Input
MS1, MS2	Mode select	Mode select	Input
MRL	Mode select strobe	Mode select strobe	Input
TO	Serial data	Serial data	Output
TC	Transmitter clock	Transmitter clock	Input
TCBE	Transmit character buffer empty	Transmit character buffer empty	Output
SYNT/ABTT	Sync character	Abort pattern	Output
$\overline{SNTR/CFT}$	Reset SYNT	Reset TCBE and transmit stop flag	Input
TCBL	Strobe for TD0-TD7	Strobe for TD0-TD7	Input
RI	Serial data	Serial data	Input
RC	Receiver clock	Receiver clock	Input
DR	Receiver character buffer full	Receiver character buffer full	Output
$\overline{DRR}$	Reset DR	Reset DR	Input
CFR	...	Stop flag received	Output
ABTR	...	Abort pattern received	Output
SYNR/IDLR	Sync character received	Idle pattern received	Output
OE	Overrun error	Overrun error	Output
SYNC/$\overline{ZIP}$	Sync character input on TD0-TD7	Prohibit zero insertion pattern	Input


8228
DB0-DB7
RD0-RD7
TD0-TD7
MS1
MS2
μPD379
TC
RC
÷2TTL
8224
SYNC/ZIP
CS
8080A
A0
A1
A2
A3-A15
ADDRESS DECODER
15
3
2
1
0
1
1000
0000
0000
DEVICE ADDRESS
MS1
MS2
SYNC/ZIP

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1. Features

   a. Uses standard syndronous or SDIC protocol.
   b. Half- and full-duplex modes.

2. Mode select

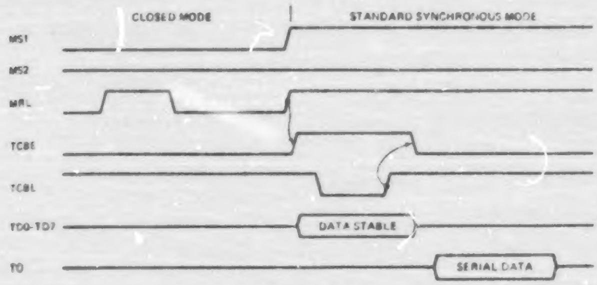
	MS1	MS2
Closed	0	X
Standard synchronous	1	0
SDLC	1	1

   a. Closed mode is used to initialize the drives.
   b. Then operating mode is chosen.

3. Standard synchronous

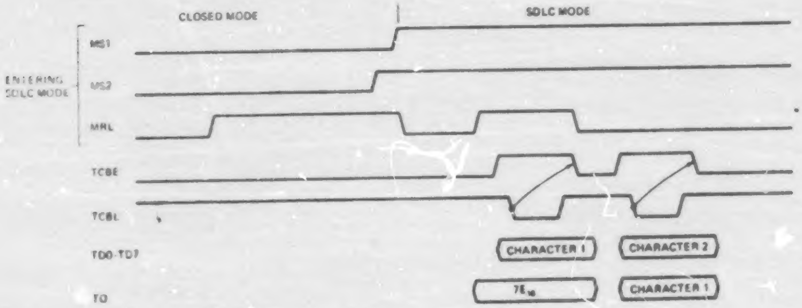
   a. To transmit data see timing in Figure 8.

FIGURE 8


CLOSED MODE
STANDARD SYNCHRONOUS MODE
MS1
MS2
MRL
TCBE
TCBL
TD0-TD7
DATA STABLE
TO
SERIAL DATA

   b. To receive data see timing in Figure 9.

FIGURE 9


CLOSED MODE
SDLC MODE
ENTERING SDLC MODE
MS1
MS2
MRL
TCBE
TCBL
TD0-TD7
CHARACTER 1
CHARACTER 2
TO
7E16
CHARACTER 1

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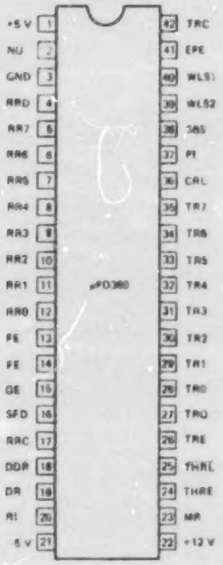
H. NEC MPD 369 Universal Asynchronous Receiver/Transmitter

1. Features

   a. Uses 8080A power (+5-5 and +12V)
   b. Half- or full-duplex operation
   c. Variable band rates (DC to 50K band)


+5 V
NU
GND
RRD
RR7
RR6
RR5
RR4
RR3
RR2
RR1
RR0
PE
FE
OE
SFD
RRC
DDR
DR
RI
-5 V
TRC
EPE
WLS1
WLS2
SBS
PI
CRL
TR7
TR6
TR5
TR4
TR3
TR2
TR1
TR0
TRO
TRE
THRL
THRE
MR
+12 V
μPD369

μPD369 Signals

Signal	Description	Type
RR0–RR7	Parallel received data	Output
TR0–TR7	Parallel transmit data	Input
TRO	Serial data	Output
RI	Serial data	Input
MR	Master reset	Input
TRC	Transmit clock	Input
RRC	Receive clock	Input
PI	Parity inhibit	Input
SBS	Stop bits select	Input
WLS1, WLS2	Word length select	Input
EPE	Even/odd parity select	Input
CRL	Control load	Input
TRE	Transmit register empty	Output
THRE	Transmit holding register empty	Output
$\overline{\text{THRL}}$	Transmit holding register load	Input
PE	Parity error	Output
FE	Framing error	Output
OE	Overrun error	Output
SFD	Status flag disconnect	Input
DR	Data received	Output
$\overline{\text{DRR}}$	Data received reset	Input
RRD	Parallel data read strobe	Input

2. Transmission is doubled buffered. See Figure 10 and Figure 11.

   a. 1 holding buffer
   b. 1 data buffer

FIGURE 10

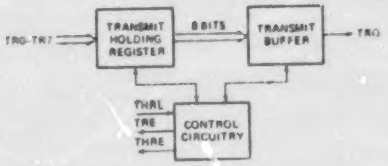
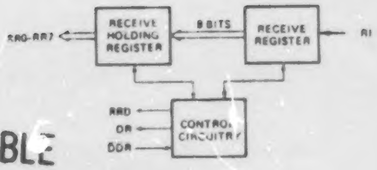

TR0-TR7
TRANSMIT HOLDING REGISTER
8 BITS
TRANSMIT BUFFER
TRO
THRL
TRE
THRE
CONTROL CIRCUITRY

FIGURE 11


RR0-RR7
RECEIVE HOLDING REGISTER
8 BITS
RECEIVE REGISTER
RI
RRD
DR
DDR
CONTROL CIRCUITRY

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INFORMATION SHEET

P. Synchronous serial protocol - transmitter supplies data on every clock perke. Use for rates over 2,000 band.

Q. Asynchronous serial protocol - transmitter supplies data only when there is data to send. Used for rates below 2,000 band. Asynchronous efficiency is lower than synchronous because asynchronous needs a sync unit.

R. Synchronous data link control - used in networks with a single primary and multiple secondary stations. Secondaries cannot communicate with one another. Data is sent in groups with the address and control fields each being 8 bits long.

S. High level data link control - a protocol used in networks with a single primary and multiple secondaries. Data is sent with the address being any length. The central field is 8 or 16 bits long.

II. Two sets of codes commonly used by input and output equipment are BCD and ASCII.

III. There are three methods of error detection.

A. Parity check. Each I/O binary is either checked for odd or even number of bits to determine whether a bit was lost or gained transmission.

B. Check sum. The transmitting station adds all the bits in the data to be transmitted and transmits the total along with the data. The receiving station does the same and compares the total bits to see if a bit was picked up or dropped.

C. Cylclic redundancy check. A circuit which can compute a bit loss or gain which uses less bits than A or B.

IV. Input and output devices

A. Printers - output

1. Types
   a. Serial - one letter at a time
   b. Line - one 48+28 line at a time

2. Speed

   a. Slow - 30 char/sec
   b. Fast - 1000's lines/mim

INPUT/OUTPUT
UNIT II

LAB SHEET #1 - I/O USING HEXIDECIMAL DISPLAY

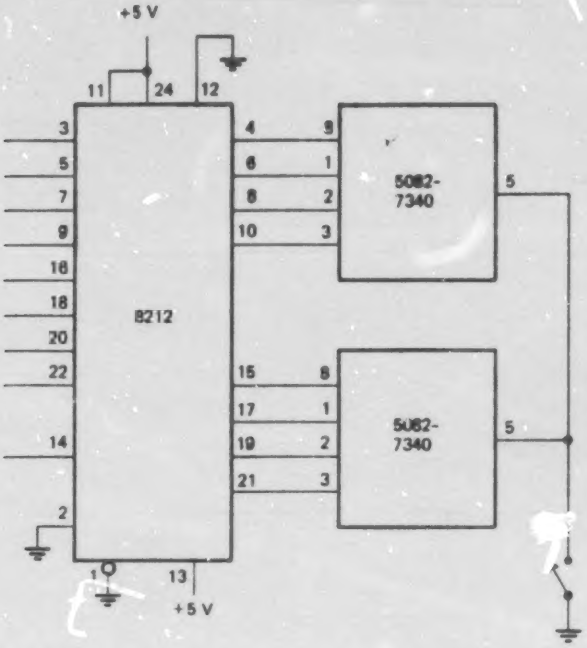
I. Equipment

A. 1-8212
B. 2-5082-7340 Hex display
C. +5V power supply
D. Breadboard
E. Hook-up wire

II. Procedure

A. Construct the circuit shown in Figure 1.

FIGURE 1


+5 V
11
24
12
3
5
7
9
16
18
20
22
14
2
8212
1
13
+5 V
4
6
8
10
15
17
19
21
8
1
2
3
5082-
7340
5
8
1
2
3
5082-
7340
5

B. Connect DIO input to +5V and ground DI1 through DI7. What value is shown in the hexadecimal display?__________________

____

C. If you did not see 01_{16} you should recheck your circuit.

D. Complete the following table, filling in the table with a high or low indication.

LAB SHEET #1

E.

	Input Pins							
Display	DI7	DI6	DI5	DI4	DI3	DI2	DI1	DI0
01								
03								
07								
70								
1F								
3F								
FF								

F. Your results should look like the table below.

	DI7	DI6	DI5	DI4	DI3	DI2	DI1	DI0
01	L	L	L	L	L	L	L	H
03	L	L	L	L	L	L	H	H
07	L	L	L	L	L	H	H	H
70	L	H	H	H	L	L	L	L
1F	L	L	L	H	H	H	H	H
3F	L	L	H	H	H	H	H	H
FF	H	H	H	H	H	H	H	H

G. Have your instructor observe your results.

H. Turn off your power.

I. Save your circuit for the next experiment.

INPUT/OUTPUT

UNIT II

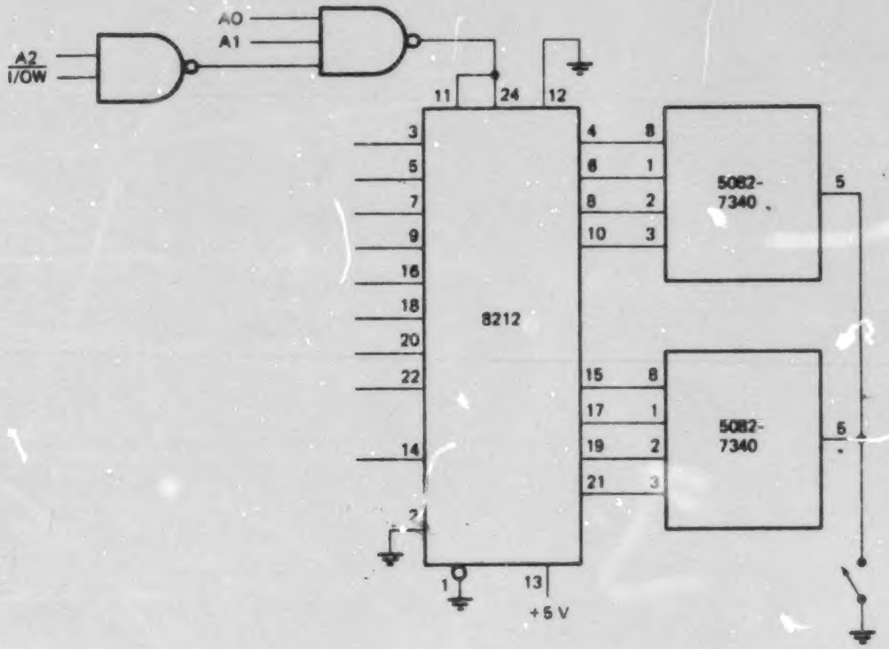
LAB SHEET #2 - USING I/O HEX DISPLAY WITH A MICROCOMPUTER

I. Equipment

- A. 1-Microcomputer
- B. 1-8212
- C. 1-5082-7340 Hex display
- D. 1-74LS20
- E. +5 volt power supply
- F. Breadboard
- G. Hook-up wire

II. Procedure

- A. Use the circuit from lab sheet #1.
- B. Add the necessary additional wiring to your circuit.


A0
A1
A2
$\overline{I/OW}$
11
24
12
3
5
7
9
16
18
20
22
14
2
1
13
+5 V
8212
4
6
8
10
8
1
2
3
5082-7340
5
15
17
19
21
8
1
2
3
5082-7340
5

LAB SHEET #2

C. Load the following program into your microcomputer:

Instruction	Address	Machine Code
LDA DATA	0000	3A
	0001	06
	0002	00
OUT 7	0003	D3
	0004	07
HLT	0005	76
DATA	0006	01

D. Execute the program. Your display should show 01_{16}.

E. Now write a program to output the numbers 00_{16} - FF_{16} with a 1 sec delay between each output.

F. One way to do this is to increment the valve in 0006_{16} then call the output subroutine followed by a return to delay and increment.

G. Show your results to your instructor.

H. Turn off your power.

I. Put up your equipment.

INPUT/OUTPUT
UNIT II
TEST

NAME____ SCORE__________

1. Match terms associated with I/O to their correct definitions. Place the correct number in the blank.

____a. Rate of transferring data.

____b. ASCII and BCD-used by peripheral equipment and translated to binary's and 0's to be used by internal IC's.

____c. I/O data is transferred one bit at a time.

____d. Methods such as parity, check series and CRC are used to insure correction data transmission and error detection.

____e. I/O data is transferred in groups of bits.

____f. Equipment such as printer, keyboards, CRT terminals, modems, floppy disk drives, and magnetic tape recorders.

____g. A controller that prevents a decrease in processing speed by performing high speed transfers between memory and I/O devices.

____h. Data can be transferred in or out of the microprocessor through the accumulator.

_____i. The 8080A can use up to 8 - 8259 (PICU) to provide 64 levels of interrupt activity.

_____j. A device that connects a microprocessor with I/O equipment and makes necessary changes to make both compatible.

_____k. The 8080A has two sets of instruction to handle interrupts-control and vectoring.

_____l. A temporary storage used in I/O operation to provide signal stability and increase operational speed.

____m. A signal that causes the microprocessor to stop normal processing and begin an interrupt sequence.

1. High level data link control
2. Synchronous data link control
3. Asynchronous serial protocol
4. Synchronous serial protocol
5. Bank rate
6. Serial data exchange
7. Parallel data exchange
8. Direct memory access
9. Codes
10. Priority interrupt control circuit
11. Interrupt instruction
12. Memory mapped I/O
13. Interrupt
14. I/O parts
15. Interfacing
16. Buffering
17. Accumulator I/O
18. Peripheral equipment
19. Error detection

TEST

____n. Method in I/O operations where I/O devices are given memory addresses.

____o. A buffer made up of flip-flops for latches.

____p. A protocol used in networks with a single primary and multiple secondaries.

____q. Transmitter supplies data on every clock perke.

____r. Transmitter supplies data only when there is data to send.

____s. Used in networks with a single primary and multiple secondary stations.

2. List two commonly used I/O codes.

   a.

   b.

3. Name three methods of error deletion.

   a.

   b.

   c.

4. List devices used for I/O.

TEST

5. Describe how information is read from the accumulator.

6. Use a binary cycle to explain the operation of an I/O port.

7. Four advantages of memory mapped I/O:

   a.

   b.

   c.

   d.

8. Describe an interrupt sequence.

   a.

   b.

   c.

   d.

   e.

   f.

   g.

TEST

9. Use a schematic to show how the DMA can be used as an I/O port.

10. Describe the differences between asymchronous and synchronous serial receiver and transmitter.

11. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

INPUT/OUTPUT

UNIT II

TEST ANSWERS

1. a. 5
   b. 9
   c. 6
   d. 19
   e. 7
   f. 18
   g. 8
   h. 17
   i. 10
   j. 15
   k. 11
   l. 16
   m. 13
   n. 12
   o. 14
   p. 1
   q. 4
   r. 3
   s. 2

2. BCD & ASCII

3. Parity check
   Check sum
   Cyclic redundancy

4. Printer
   Keyboard
   CRT
   Modem
   Floppy disk
   Magnetic tape

5. Output

   1. The output instruction requires 3 machine cycles.
   2. MC 1 - instruction is fetched and interpreted.
   3. MC 2 - the device code is read.
   4. MC 3 - data is set out.

6. I/O port - 8212 is 8 bit latch used for I/O.

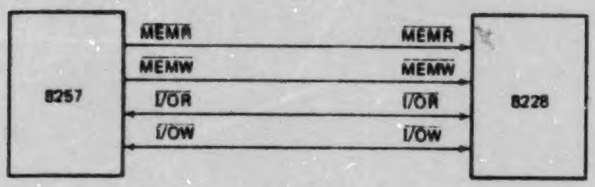
7. A. General purpose register
   B. Faster than accumulator
   C. More than 256 device codes
   D. Data directly usable.

TEST ANSWERS

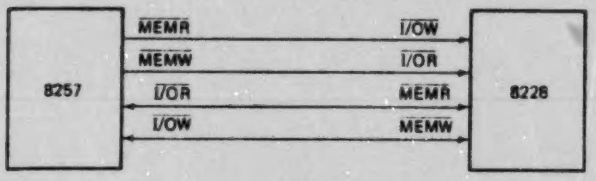
8. Example procedure

    1. Complete current instruction
    2. Clears interrupt flip-flop
    3. Take service program address from data lines
    4. Saving next program address
    5. Jump to vector address
    6. Begin processing program
    7. Either halt or pull last regular program address to stack

9.


8257
MEMR
MEMW
I/OR
I/OW
MEMR
MEMW
I/OR
I/OW
8228

(a)


8257
MEMR
MEMW
I/OR
I/OW
I/OW
I/OR
MEMR
MEMW
8228

(b)

10. Asynchronous a. Uses 8080A power (+5-5 and +12 V)
b. Half- or full-duplex operation
c. Variable band rates (DC to 50K band)

Syncnronous a. Uses standard syndronous or SDIC protocol
b. Half- and full-duplex modes

MICROPROCESSOR AND INTERFACING

UNIT III

STANDARD INTERFACES

STANDARD INTERFACES

UNIT III

OBJECTIVE

After completing this unit, the student should be able to explain the function and use of the RS232-C and IEE-488 interface and the 9-100 bus. This knowledge will be shown by completing assignment sheets, lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with interfacing to their correct definitions.
2. Describe and label the 25 pins on the RS-232C interface.
3. Describe the 16 Data and Control buses on the IEEE-488 interface bus.
4. Describe and label the 24 pins on the IEEE-488 connector.
5. Name the seven types of lines on the S-100 bus.
6. Name the five types of lines on the Multibus.
7. Demonstrate the ability to
    - A. Use a RS-232C Interface in a circuit.
    - B. Determine an IEEE-488s operating characteristics.
    - C. Use a Data bus in a circuit.

STANDARD INTERFACES

UNIT III

SUGGESTED ACTIVITIES

I. Instructor
   - A. Provide students with objective sheet.
   - B. Provide students with information and lab sheets.
   - C. Make transparencies.
   - D. Discuss unit and specific objectives.
   - E. Discuss information and lab sheets.
   - F. Demonstrate the wiring of an interface and microcomputer to some controlled device.
   - G. Discuss buses and interface uses.
   - H. Assist students with wiring and troubleshooting buses and interfaces.
   - I. Give test.

II. Student
   - A. Read objective sheets.
   - B. Study information sheets.
   - C. Complete lab sheets.
   - D. Take test.

STANDARD INTERFACES

UNIT III

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Information sheets.

   C. Assignment sheets.

   D. Lab sheets.

   E. Test.

   F. Answers to assignment sheets.

   G. Answers to test.

II. References

   A. Pasahow, Edward J., Microprocessors and Microcomputer, New York, New York, McGraw-Hill Book Co., 1981.

   B. Camp, Smay, Triska, Microprocessor Systems Engineering, Beaverton, Oregon, Matrix Publishers, 1979.

   C. Rony, Peter R., Introductory Experiments in Digital Electronic and 8080A Microcomputer Programming and Interfacing VI, Indianapolis, Indiana, Howard W. Sams & Co.

   D. Pasahow, Edward J., Microcomputer Interfacing, New York, New York, McGraw-Hill Book Co., 1981.

   E. Staugaard, Andrew C., Microprocessor Interfacing, Benton Harbor, Michigan, Heath Co., 1982.

   F. Hall, Douglas V. and Marybelle B., Experiments in Microprocessors and Digital System, New York, New York, McGraw-Hill Book Co., 1983.

   G. Brey, Barry B., Microprocessor Hardware Interfacing And Applications, Columbus, Ohio, Charles E. Merrill Publishing Co., 1984.

STANDARD INTERFACES

UNIT III

PROCEDURE SHEET

______1.	Study	Information Sheets.
______2.	Study	Chapters 7, 8, and 9 Microcomputer Interfacing, Pasahow.
______3.	Do	Lab sheets #1 - Using the RS-232C Interface.
______4.	Do	Lab Sheet #2 - Investigating the IEEE-488 Interface.
______5.	Write	An informal lab report for Lab Sheet #2 Investigating the IEEE-488 Interface.
______6.	Do	Lab Sheet #3 - Using Data Buses.
______7.	Stop	If your instructor is satisfied with the lab sheet results, continue onto Step 8. Otherwise consult with your instructor for further work.
______8.	Turn-in	Your informal lab report.
______9.	Review	Chapters 7, 8, and 9, Information Sheets and Lab Sheets.
_____10.	Complete	Unit Test - Standard Interfaces.

STANDARD INTERFACES

UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Interface - the interconnection of the data terminal equipment (DTE) and data communication equipment (DCE).

B. Signals - lines to/from an interface device which are made up of grounds, data, handshaking, control, and timing signals.

C. Electrical characteristics - limits on voltages, resistances and capacitances that an interface must meet.

D. Converting levels - TTL and interface equipment logic are inverted and must be connected during interfacing.

E. General-purpose interface function - these are functions that support handshaking, talking, listening, requesting service, remote controlling, polling, clearing and triggering.

F. Bus - a collection of wires that serve as a standard communication path between modules of a computer.

G. Bus signals - every message being sent has sending and receiving commands for devices on the bus.

H. Synchronous bus control - one device (MP) controls signals for all devices.

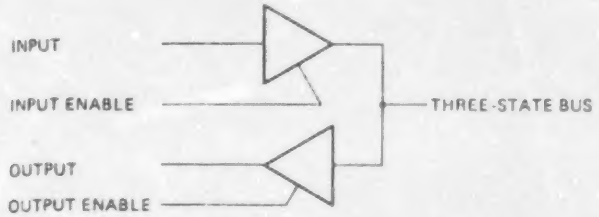
I. Asynchronous bus control - timing is generated by sender and receiver.

J. Drives - assures electrical compatibility among all devices on the bus. The drives also have high current signals to insure signals reach destination.

K. Receivers - can be AND gates with a select or enable line to open path to device from bus.

L. Bus transceiver - an example is shown in Figure 1.

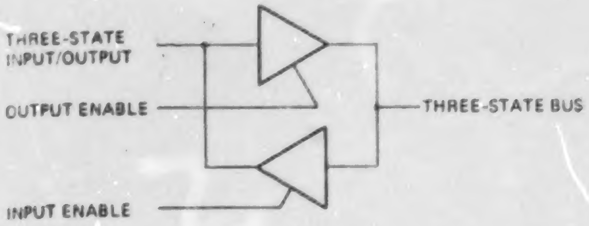
FIGURE 1



INFORMATION SHEET

M. Bus bidirectional driver - an example is shown in Figure 2.

FIGURE 2


THREE-STATE INPUT/OUTPUT
OUTPUT ENABLE
INPUT ENABLE
THREE-STATE BUS

N. S-100 Bux - has 100 parallel lines to be used with the 8080A. The lines are similar to those of the 8080A.

O. Multibus - a bus that allows connecting computers, memory, I/O boards and peripheral controllers.

II. RS-232C

A. Characteristics

1. Assign serial signals to pins.
2. Unrestricted data type.
3. Character length, code and sequence.
4. Asynchronous or synchronous capability.
5. Cable length maximum is 50 ft.
6. Band into to 20K.

B. Signals (25 pins)

1. Logic 1 is -3 to -25 V.
2. Logic 0 is +3 to +25 V.

INFORMATION SHEET

Pin number	Circuit	Common abbreviation	Description
1	AA	...	Protective ground
2	BA	TXD	Transmitted data
3	BB	RXD	Received data
4	CA	RTS	Request to send
5	CB	CTS	Clear to send
6	CC	DSR	Data set ready
7	AB	...	Signal ground (common return)
8	CF	DCD	Received line signal detector
9	...	...	Reserved for data set testing
10	...	...	Reserved for data set testing
11	...	...	Unassigned
12	SCF	...	Secondary received line signal detector
13	SCB	...	Secondary clear to send
14	SBA	...	Secondary transmitted data
15	DB	...	Transmission signal element timing (DCE source)
16	SBB	...	Secondary received data
17	DD	...	Receiver signal element timing (DCE source)
18	...	...	Unassigned
19	SCA	...	Secondary request to send
20	CD	DTR	Data terminal ready
21	CG	...	Signal quality detector
22	CE	...	Ring indicator
23*	CH/CI	...	Data signal rate selector (DTE/DCE source)
24	DA	...	Transmit signal element timing (DTE source)
25	...	...	Unassigned

*Only one of these two signals is tied to pin 23.

3. BA generated by DTE (peripherals). DTE generates this between transmission.
4. CA, CB, CC, and CD must be high before BH goes high.
5. BB generates by DCE (computer). Must be high when CF is off.
6. CF will be 1 in a half-duplex system when CA is on.
7. TXD - transmitted data signal.
8. RXD - received data signal.
9. SBA is the secondary channel equivalent of BA.
10. SBB is the secondary channel equivalent of BB.

C. Control

1. CA originated by DTE. In one way equipment high represents transmit mode. Half-duplex equipment, represent transmit and exhibit receive.
2. CB must be turned off to again turn on CA.
3. CB originated by DCE in response to CC and CA being high.
4. CC represents the on connection or when the equipment is not in test, talk or dial mode.
5. CD circuit connects the DCE to the channel and disconnects when off after completion of transmission.
6. CE means that the DCE is receiving a ringing.
7. CF is on when DCE is receiving a suitable signal.
8. CG is on when DCE believes that no error has occurred.
9. CH or CI signals which rate is being used.
10. CSF is the secondary channels equivalent of CF.

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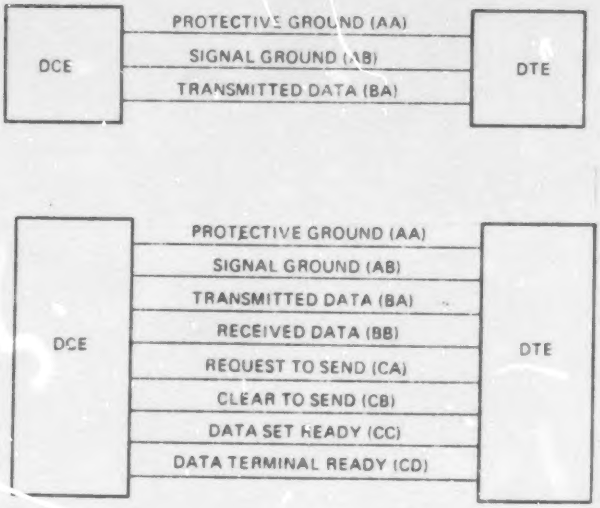
D. Timing

1. DA is sent by DTE to indicate the center of each bit on the transmitted data line.
2. DB is set by DCE to indicate to the data terminal a time for data change.
3. DD is set by DCE to indicate the center of each bit received on the date line.

E. Common sample

1. Most lines won't be used most of the time as seen in Figure 1.

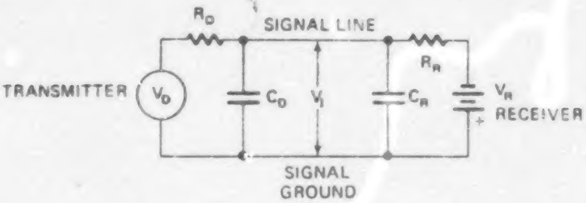
FIGURE 1


DCE
PROTECTIVE GROUND (AA)
SIGNAL GROUND (AB)
TRANSMITTED DATA (BA)
DTE
DCE
PROTECTIVE GROUND (AA)
SIGNAL GROUND (AB)
TRANSMITTED DATA (BA)
RECEIVED DATA (BB)
REQUEST TO SEND (CA)
CLEAR TO SEND (CB)
DATA SET READY (CC)
DATA TERMINAL READY (CD)
DTE

F. Electrical Characteristics

1. A typical circuit is shown in Figure 2.

FIGURE 2


R_D
SIGNAL LINE
R_R
TRANSMITTER
V_D
C_D
V_I
C_R
V_R
RECEIVER
SIGNAL GROUND

INFORMATION SHEET

2. RΩ must be between 3000Ω to 7000 Ω at voltages less than 250 V.
3. CΩ must be less than 2.5 nF.
4. Line receivers must be able to withstand ∓ 25 V. inputs.
5. The inactive component must not be inductive.
6. Power off source impedance must be greater than 300Ω.

G. Mechanical any 25 pin connector may be used with DB-25P or DB-255 being typical examples.

H. Level conversion

1. TTL to interface can be accomplished with TTL
    - a. OP amp
    - b. TTL
    - c. Opto-isolator (4N33)
2. TTL to interface can be accomplished with IC converters such as 148841489.
3. Interface to TTL conversion can be accomplished with TTL.

III. IEEE-488 Bus

A. Signals (16 lines). See Figure 3.

FIGURE 3

GPIB Data and Control Buses

Bus	Line	Signal
Data bus	DIO1	Data input output 1
	DIO2	Data input output 2
	DIO3	Data input output 3
	DIO4	Data input output 4
	DIO5	Data input output 5
	DIO6	Data input output 6
	DIO7	Data input output 7
	DIO8	Data input output 8
Data byte transfer control (handshaking)	DAV	Data valid
	NDAC	No data accepted
	NRFD	Not ready for data
General interface management	ATN	Attention
	IFC	Interface clear
	SRQ	Service request
	REN	Remote enable
	EOI	End or identify

1. DIO1-DIO8. Input/output lines to transfer data byte.
2. Handshaking interlocking control is maintained by the next 3 lines: DAU, NDAC, and NRFD.
3. General management is controlled by the last 5 lines: ATN, IFC, SRQ, REN, EOI

INFORMATION SHEET

B. Functional repertoire. See Figure 4.

FIGURE 4

Functional Repertoire

Interface function	Symbol
Source handshake	SH
Acceptor handshake	AH
Talker or extended talker	T/TE
Listener or extended listener	L/LE
Service request	SR
Remote local	RL
Parallel poll	PP
Device clear	DC
Device trigger	DT
Controller	C

1. SH controls "talking" devices and allows it to transfer data.
2. AH return as SH code from "talking".
3. T/TE line for device dependent data.
4. L/LE line receiver device dependent data.
5. SR line sends request from controller to device.
6. RL disable the control panel controls.
7. PP line allows eight devices to send data to I/O lines.
8. DC line cleans all devices.
9. DT line is for remote starting.
10. C line initiates controller commands.

C. Electrical characteristics

1. TTL used for all signals.
2. Logic 0 is high.
3. Logic 1 is low.
4. Open collector drives can be used for all drives.
5. Three state devices can be used for length speed (met NRED & NDAC).
6. Drives low voltage must be 0.5 V. or less and able to send +48 MA without damage.
7. High output is equal to or greater than 2.4 V. at - 5.2 MA. Max voltage is 5 V.
8. Make all measurements at the device connector between signal and logic ground.
9. Receiver logic input voltage will be between -0.6 and 0.8 V. in the low state.
10. High input will be between 2 and 5.5 V.
11. Every signal line is terminated in a resistive load.

INFORMATION SHEET

12. The capacitive load is 100pF within each device.
13. The bus should have no more than 0.14 r/m and common logic ground cannot exceed 0.085 r/m.
14. The transceiver circuit can be of the MC3440P or MC3441P type.

D. Connectors should be of a rack and panel type to permit daisy chaining. Voltage rate is 200 VOC and SA per contact. Contact resistance must exceed 1 gigo hr. Pin assignments are listed in Figure 5.

FIGURE 5 Connector Pin Assignments

Pin	Signal
1	DIO1
2	DIO2
3	DIO3
4	DIO4
5	EOI
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	SHIELD (earth ground)
13	DIO5
14	DIO6
15	DIO7
16	DIO8
17	REN
18	DAV ground
19	NRFD ground
20	NDAC ground
21	IFC ground
22	SRQ ground
23	ATN ground
24	LOGIC ground

E. Controller communications to listeners

1. ATN within 200 nsec
    a. False = command signal
    b. True = data signal
2. Minimal interface need D101-D108, DAU, NRED, and NDAC
3. Last byte is labeled: EOI = 1 to know transfer is complete
4. REN disables the front panel
5. REN high reverts an instrument to manual control
6. Service can be requested by sending SRQ to controller--this acts as interrupt.

INFORMATION SHEET

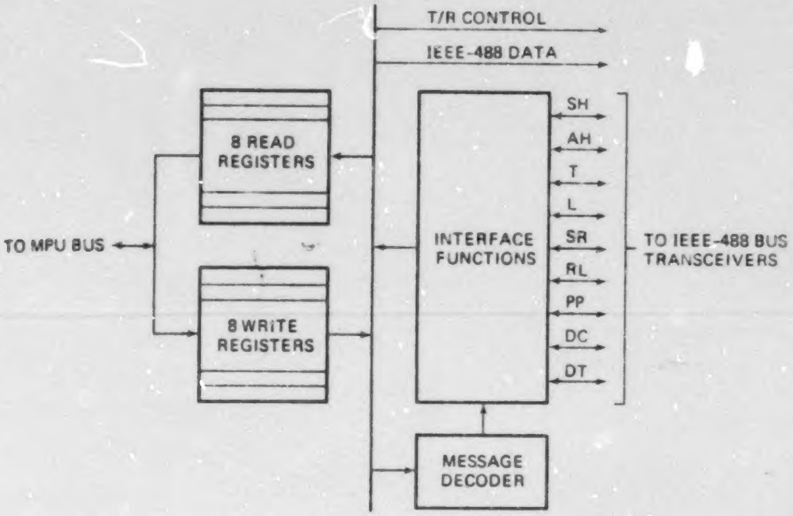
F. Polling

1. Controller can poll eight instruments in parallel fashion.
2. To initiate, controller drops EOl and ATN.
3. Each instrument responds with 1 or 0.

G. IC interfaces

1. A typical talker/listener chip is shown in Figure 6.

FIGURE 6


T/R CONTROL
IEEE-488 DATA
8 READ REGISTERS
TO MPU BUS
8 WRITE REGISTERS
INTERFACE FUNCTIONS
SH
AH
T
L
SR
RL
PP
DC
DT
TO IEEE-488 BUS TRANSCEIVERS
MESSAGE DECODER

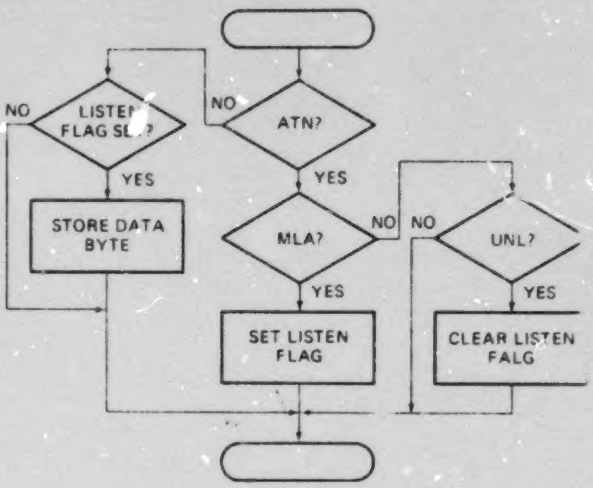
2. The 8291 provides complete handshaking sequences.
3. The 8291 also can
    a. request service
    b. parallel poll
    c. send device clear
    d. trigger
    e. local/remote commands
    f. recognize primary or secondary addresses
    g. read or write memory data without MPU if a DMA is provided
    h. A 8292 initialize a bus with the IFC signal

H. Sofeware interface

1. Software in the MP instead of IC can be used
2. The MP program can be initiated from an interrupt
3. Figure 7 is a sample of the steps followed by the software program.

INFORMATION SHEET

FIGURE 7


NO
LISTEN FLAG SET?
YES
STORE DATA BYTE
NO
ATN?
YES
MLA?
NO
YES
SET LISTEN FLAG
NO
UNL?
YES
CLEAR LISTEN FALG

III. S-100 Bus

A. Lines

1. 8 - data input lines
2. 8 - data output lines
3. 16 - address lines
4. 4 - power supply lines
5. 8 - interrupt lines
6. 2 - ground lines
7. 38 - control lines

B. I/O lines

1. Data input is used to transfer data to the processor
2. Data output is used to transfer data to the slave module

C. Address - 16 bit buffered bus

D. Command/control bus - buffered signals to control other bus information

E. Status bus signals are latched by 8212 I/O part

F. Electrical specification are shown in Figure 8

INFORMATION SHEET

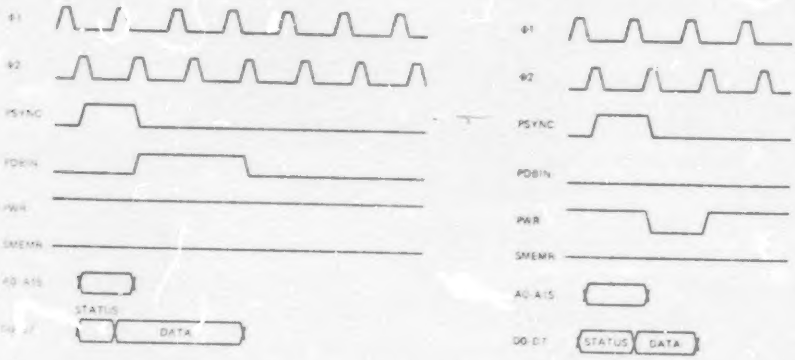
FIGURE 8

S-100 Electrical Characteristics

	Voltage, V		Current	
	Max	**Min**	**Max**	**Min**
Driver				
High	+5.5	+2.4		−1.2 mA
Low	0.5	0		+24 mA
Receiver				
High	+5.5	+2.0	+40 μA	
Low	+0.8	−0.6	−0.8 mA	

G. Timing is similar to the 8080A (as shown in Figure 9).

FIGURE 9



φ1
φ2
PSYNC
PDBIN
PWR
SMEMR
A0-A15
STATUS
D0-D7
DATA
φ1
φ2
PSYNC
PDBIN
PWR
SMEMR
A0-A15
D0-D7
STATUS
DATA

H. Disadvantages

1. Power variation for boards at distances
2. Unused pins are sometimes used by different manufacturers
3. Capacitive loading can occur since the bus is not buffered

IV. Multibus

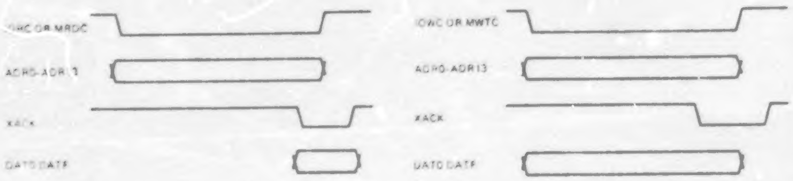
A. Lines

1. 20 - address bus lines
2. 16 - bidirectional data bus lines
3. 8 - multilevel interrupt lines
4. Control and timing
5. Power distribution

INFORMATION SHEET

B. Reading and writing timing as shown in Figure 10.

FIGURE 10



C. Electrical specifications are shown in Figure 11.

FIGURE 11

Multibus Electrical Specifications

Signals	Output stage	Minimum driver current, mA	Maximum receiver current, mA	Termination, Ω
$\overline{\text{DAT0–DATF}}$	Three state	16	−0.8	2200
$\overline{\text{ADR0–ADR13}}$	Three state	16	−0.8	2200
$\overline{\text{MRDC}}$,$\overline{\text{MWTC}}$	Three state	32	−2	1000
$\overline{\text{IORC}}$,$\overline{\text{IOWC}}$	Three state	32	−2	1000
$\overline{\text{XACK}}$	Three state	32	−2	510
$\overline{\text{INH1}}$,$\overline{\text{INH2}}$	Open collector	16	−2	1000
$\overline{\text{BCLK}}$,$\overline{\text{CCLK}}$	Three state	48	−2	220 and 330
$\overline{\text{BREQ}}$	Three state	5	2	100
$\overline{\text{BPRO}}$	Three state	5	−1.6	...
$\overline{\text{BPRN}}$	Three state	5	−2	...
$\overline{\text{BUSY}}$,CBRQ	Open collector	32	−2	1000
$\overline{\text{INIT}}$	Open collector	32	−2	2200
$\overline{\text{INTA}}$	Three state	32	−2	1000
$\overline{\text{INT0–INT7}}$	Open collector	16	−1.6	1000
$\overline{\text{PFSR}}$,$\overline{\text{PFSN}}$	Three state	16	−1.6	1000
ACLO	Open collector	16	−1.6	1000
$\overline{\text{PFIN}}$	Open collector	16	−1.6	1000
$\overline{\text{MPRO}}$	Three state	16	−1.6	1000
$\overline{\text{AUXRESET}}$	...	...	−2	...

STANDARD INTERFACES

UNIT III

LAB SHEET #1 - USING THE RS-232C INTERFACE

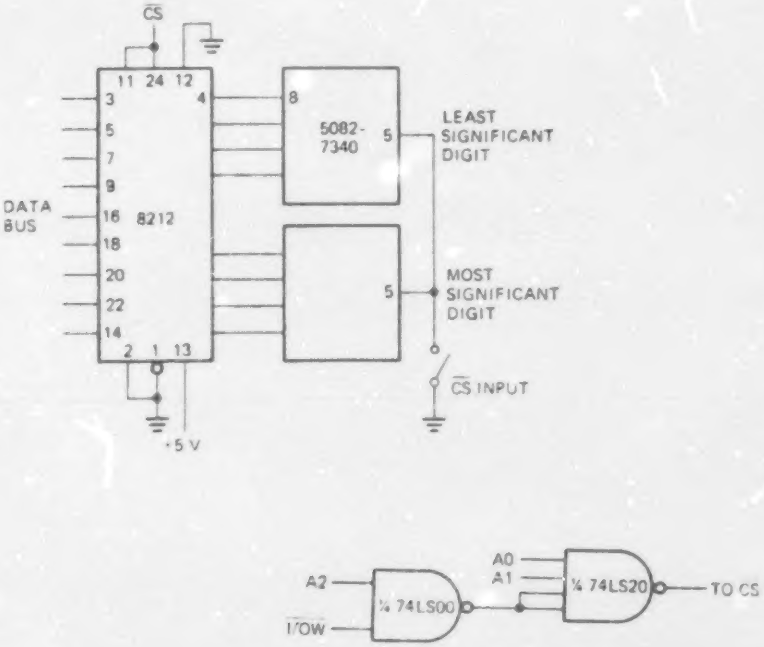
I. Equipment

A. 1-8212
B. 1-74L500
C. 1-74L520
D. 1-4N33
E. 1-5082 - 7340 .
F. 1-1KΩ resistor
G. 1-680Ω resistor
H. +5V and 12V power supply logic probe

II. Procedure

A. Connect the circuits shown in Figure 1.

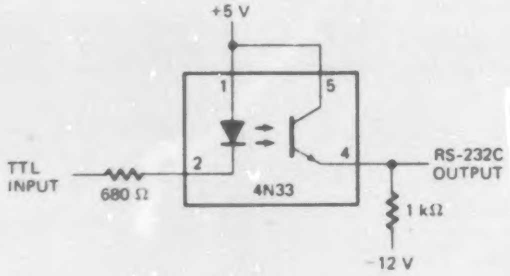
FIGURE 1


CS
11 24 12
4
3
5
7
9
16
18
20
22
14
2 1 13
DATA BUS
8212
+5 V
8
5082-7340
5
LEAST SIGNIFICANT DIGIT
5
MOST SIGNIFICANT DIGIT
CS INPUT
A2
I/OW
¼ 74LS00
A0
A1
¼ 74LS20
TO CS

LAB SHEET #1

B. Connect the TTL-to-R5232C converter as shown in Figure 2.

FIGURE 2



Test the converter circuit by applying a pulser to the input and check the results with a logic probe.

C. Connect the RS-232C output to the received data pin of your computer terminal. Tie sequal ground and protective ground pins of the terminal to the microcomputer ground.

D. Referring to the operators' manual for your terminal, output a series of characters by the programs listed below.

Label	Mnemonic	Address	Op code	Comment
	MVI D, 11	1000	16	Set bit counter to 11
		1008	0B	
	MOV A, E	1002	7B	Place data in accumulator
	ORA A	1000	B7	Clear carry bit
	RAL	1000	17	Carry A bit 0 of accumulator to act as start bit
LOOP	OUT OF	1005	D3	Send data on port $0F_{16}$
		1006	0F	
	CALL DELAY	1007	CD	9.1-ms delay subroutine
		1000	50	
		1009	10	
	RAR	100A	1F	
	STC	100B	37	Set carry for stop bits
	DCR D	100C	15	Decrement bit counter
	JNZ LOOP	100D	C2	Is counter 0? If not, go to send next character
		100E	05	
		100F	10	
		1010	76	Stop.
DELAY	MVI B, 6	1050	06	Load outer loop counter to perform outer loop six times
		1051	06	
OUTLOOP	MVI C, 202	1052	0E	Load inner loop counter to perform inner loop 202 times
		1053	CA	
INLOOP	DCR C	1054	0D	Decrement inner counter
	JNZ INLOOP	1055	C2	If not zero, go to decrement again
		1056	54	

LAB SHEET #1

Label	Mnemonic	Address	Op code	Comment
		1057	10	
	DCR B	1058	05	Decrement outer counter
	JNZ OUTLOOP	1059	C2	If not zero go to decrement again
		105A	52	
		105B	10	
	RET	105C	C9	Return

(NOTE: Also use device code 07. Probably you will need to change more of the program to meet the needs of your system.)

E. Have your instructor observe the output.

F. Put up your equipment.

STANDARD INTERFACES

UNIT III

LAB SHEET #2 - INVESTIGATING THE IEEE-488 INTERFACE

I. Equipment

A. 1-IEEE-488
B. 1-Operation manual

II. Procedure

A. Though reading the operations manual, is your instrument a talker, listener, controller or a combination?

____

B. Describe how to program the instrument for bus operation.

____

____

____

____

C. What device-dependent messages does the equipment receive or transmit? ______________________________________

____

____

____.

D. If the instrument sends a status byte, explain the settings of each bit. ____

____

____

STANDARD INTERFACES

UNIT III

LAB SHEET #3 - USING DATA BUSES

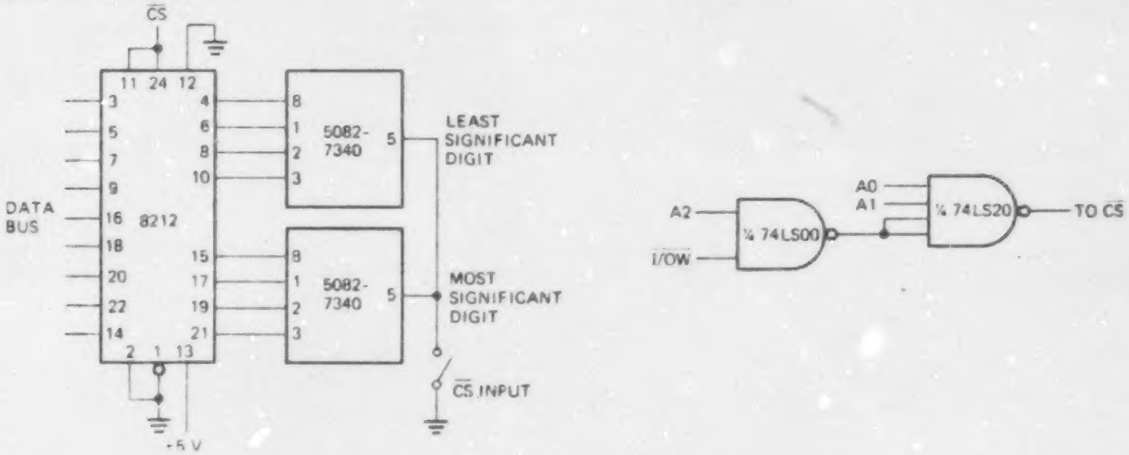
I. Equipment

A. 1-8212
B. 1-5082-7340
C. 1-742500
D. 1-74C520
E. +5V power supply
F. Breadboard
G. Hook-up wire

II. Procedure

A. Connect the circuit shown in Figure 1.

FIGURE 1



$\overline{CS}$
11 24 12
3
5
7
9
16
18
20
22
14
2 1 13
4
6
8
10
15
17
19
21
DATA BUS
8212
8
1
2
3
5082-7340
5
LEAST SIGNIFICANT DIGIT
MOST SIGNIFICANT DIGIT
$\overline{CS}$ INPUT
+5 V
A2
$\overline{I/OW}$
¼ 74LS00
A0
A1
¼ 74LS20
TO $\overline{CS}$

B. Write a program to count from 00_{16} - FF_{16} and output each value to device 07_{16}. Jump back to the beginning of the program after the program counts FF_{16}. Include a 1 sec delay.

C. Connect the data bus to the parallel interface and start the program. Record the first 16 outputs from the hexadecimal display.

D. Sketch on a separate piece of paper how these outputs appear as digital peeke train. (ex. 01_{16} would be 7 lows and 1 high)

E. Show the results to your instructor.

F. Put up your equipment.

STANDARD INTERFACES

UNIT III

TEST

NAME____SCORE________

1. Match terms associated with interfacing to their correct definitions. Place the correct number in the proper space.

____a. Has 100 parallel lines to be used with 8080A.

____b. Bus bidirectional driver.

____c. A bus that allows connecting computers, memory, I/O boards and peripheral controllers.

____d. Bus transceiver

____e. The interconnection of the data terminal equipment (DTE) and data communication equipment (DCE).

____f. Lines to/from an interface device which are made up of grounds, data, handshaking, control, and timing signals.

____g. A collection of wires that serve as a standard communication path between modules of a computer.

____h. Timing is generated by sender and receiver.

____i. Can be AND gates with a select or enable line to open path to device from bus.

____j. Assures electrical compatibility among all devices on the bus.

____k. One device (MP) controls signals for all devices.

____l. Every message being sent has sending and receiving commands for devices on the bus.

____m. These are functions that support handshaking, talking, listening, requesting service, remote controlling, polling, clearing and triggering.

1. Interface
2. Drives
3. Receivers
4. Asynchronous bus control
5. Synchronous bus control
6. Bus
7. Bus signals
8. Converting levels
9. General-purpose interface function
10. Electrical characteristics
11. Signals
12. S-100 Bus
13. Multibus
14.
15.

TEST

____n. Limits on voltages, resistances and capacitances that an interface must meet.

____o. TTL and interface equipment logic are inverted and must be connected during interfacing.

2. Describe the 25 pins on the RS-232C interface.

Pin number	Circuit	Description
1	AA	
2	BA	
3	BB	
4	CA	
5	CB	
6	CC	
7	AB	
8	CF	
9		
10		
11		
12	SCF	
13	SCB	
14	SBA	
15	DB	
16	SBB	
17	DD	
18		
19	SCA	
20	CD	
21	CG	
22	CE	
23	CH/CI	
24	DA	
25		

3. Label the 24 connector pins on the following 8291AIC:

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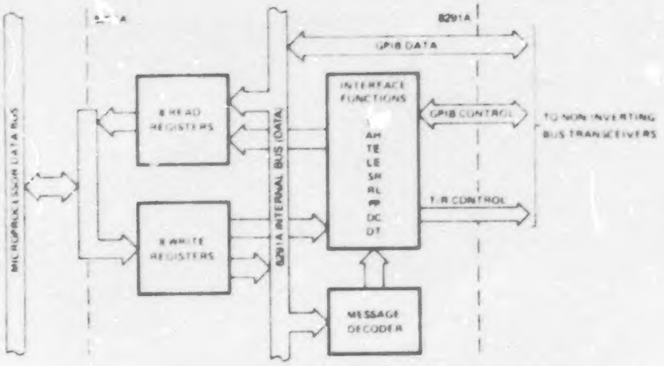
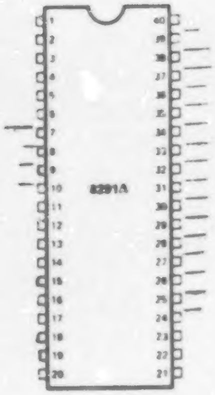
TEST


MICROPROCESSOR DATA BUS
8291A
8291A
GPIB DATA
8 READ REGISTERS
8 WRITE REGISTERS
8291A INTERNAL BUS (DATA)
INTERFACE FUNCTIONS
AH
TE
LE
SH
RL
PP
DC
DT
GPIB CONTROL
T/R CONTROL
TO NON INVERTING BUS TRANSCEIVERS
MESSAGE DECODER


8291A
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21

4. Name the seven types of lines on the 5-100 Bus.

   a.

   b.

   c.

   d.

   e.

   f.

   g.

5. Name the five types of lines on the Multibus.

   a.

   b.

   c.

   d.

   e.

6. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

STANDARD INTERFACES

UNIT III

TEST ANSWERS

1. a. 12
   b. 15
   c. 13
   d. 14
   e. 1
   f. 11
   g. 6
   h. 4
   i. 3
   j. 2
   k. 5
   l. 7
   m. 9
   n. 10
   o. 8

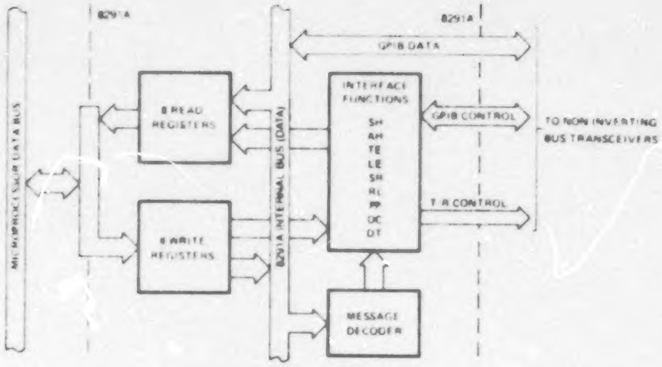
2. Descriptions:

   1. Protective ground
   2. Transmitted data
   3. Received data
   4. Request to send
   5. Clear to send
   6. Data set read
   7. Signal ground (common return)
   8. Received line signal detector
   9. Reserved for data set testing
   10. Reserved for data set testing
   11. Unassigned
   12. Secondary received line signal detector
   13. Secondary clear to send
   14. Secondary transmsitted data
   15. Transmission signal element timing (DCE source)
   16. Secondary received data
   17. Receiver signal element timing (DCE source)
   18. Unassigned
   19. Secondary request to send
   20. Data terminal ready
   21. Signal quality detector
   22. Ring indicator
   23. Data signal rate selector (DTE/DCE source)
   24. Transmit signal element timing (DTE source)
   25. Unassigned

3.

TEST ANSWERS

3. (cont'd)


MICROPROCESSOR DATA BUS
8291A
8291A
GPIB DATA
8 READ REGISTERS
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INTERFACE FUNCTIONS
SH
AH
TE
LE
SR
RL
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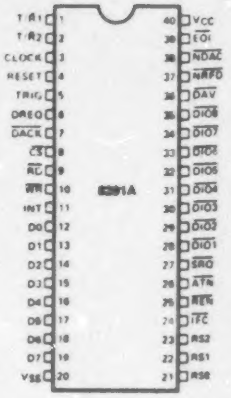
TO NON INVERTING BUS TRANSCEIVERS
T/R CONTROL
MESSAGE DECODER


8291A
T/R1 1
T/R2 2
CLOCK 3
RESET 4
TRIG 5
DREQ 6
DACK 7
CS 8
RD 9
WR 10
INT 11
D0 12
D1 13
D2 14
D3 15
D4 16
D5 17
D6 18
D7 19
VSS 20
40 VCC
39 EOI
38 NDAC
37 NRFD
36 DAV
35 DIO8
34 DIO7
33 DIO6
32 DIO5
31 DIO4
30 DIO3
29 DIO2
28 DIO1
27 SRQ
26 ATN
25 REN
24 IFC
23 RS2
22 RS1
21 RS0

4. a. Signals
   b. Functional repertorire
   c. Electrical characteristics
   d. Connectors should be of a rack and panel type to permit daisy chaining
   e. Controller communications to listeners
   f. Polling
   g. IC interfaces

5. a. 20- address bus lines
   b. 16- bidirectional data bus lines
   c. 8- multilevel interrupt lines
   d. Control and timing
   e. Power distribution

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MICROPROCESSOR AND INTERFACING

UNIT IV

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to select and connect A/D converters, D/A converters, encrytion units, sound generators, floppy disk controllers, keyboard controller and CRT controllers. This knowledge will be shown by completing lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student will be able to

1. Match terms associated with analog and digital interfaces to their correct definition.
2. List the parts of a D/A converter.
3. Name two types of D/A converter.
4. Discuss the need for a programmable converter.
5. Name five types of A/D converter.
6. Label the parts of a A/D converter.
7. Construct an encrytion and decrytion flowchart for the data encrytion unit.
8. Draw a sound generator block diagram.
9. Draw a floppy-disk controller block diagram.
10. Draw a keyboard controller block diagram.
11. Draw a CRT controller block diagram.
12. Demonstrate the ability to
    a. Use the DAC-03 D/A converter
    b. Test parallel input programs for the 7522 DAC
    c. Use a DAC-03 for A/D conversion

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet

   B. Provide students with information sheets and lab sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information and lab sheets.

   F. Demonstrate a use of a D/A converter.

   G. Demonstrate a use of a A/D converter.

   H. Demonstrate various peripheral controllers.

   I. Assist students with wiring and troubleshooting D/A converter.

   J. Assist students with wiring and troubleshooting A/D converter.

   K. Give test.

II. Student

   A. Read objective sheet.

   B. Study information sheets.

   C. Complete assignment sheets.

   D. Complete lab sheets.

   E. Take test.

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet.

   B. Information sheets.

   C. Assignment sheets.

   D. Lab sheets.

   E. Test.

   F. Answers to assignment sheets.

   G. Answers to test.

II. References

   A. Pasahow, Edward J., Microprocessors and Microcomputer, New York, New York, McGraw-Hill Book Co., 1981.

   B. Camp, Smay, Triska, Microprocessor Systems Engineering, Beaverton, Oregon, Matrix Publishers, 1979.

   C. Rony, Peter R., Introductory Experiments in Digital Electronic and 8080A Microcomputer Programming and Interfacing VI, Indianapolis, Indiana, Howard W. Sams & Co.

   D. Pasahow, Edward J., Microcomputer Interfacing, New York, New York, McGraw-Hill Book Co., 1981.

   E. Staugaard, Andrew C., Microprocessor Interfacing, Benton Harbor, Michigan, Heath Co., 1982.

   F. Hall, Douglas V. and Marybelle B., Experiments in Microprocessors and Digital System, New York, New York, McGraw-Hill Book Co., 1983.

   G. Brey, Barry B., Microprocessor Hardware Interfacing And Applications, Columbus, Ohio, Charles E. Merrill Publishing Co., 1984.

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

PROCEDURE SHEET

______1. Study — Information sheets.

______2. Study — Chapters 10 and 11 *Microcomputer Interfacing*, Pasahow.

______3. Do — Lab Sheet #1 - D/A Interfacing.

______4. Do — Lab Sheet #2 - Using the DAC-03.

______5. Do — Lab Sheet #3 - Test Parallel Input Program for the 7522.

______6. Do — Lab Sheet #4 - Using a DAC-03 for Analog to Digital Conversion.

______7. Write — An informal lab report for Lab Sheet #4 - Using a DAC-03 for Analog to Digital Conversion.

______8. Stop — If your instructor is satisfied with your Lab Sheets, continue on to step 9. Otherwise consult with your instructor.

______9. Review — Chapter 10 and 11, Information Sheets and Lab Sheets.

_____10. Complete — Unit Test - Analog/Digital Interfaces And Peripheral Equipment.

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Decision matrix - a collection of logic gates in a D/A counter to which digital inputs are applied.

B. Precision reference voltage - the voltage which is the source of the drive for the resistor network in a D/A converter.

C. Output range voltage - $V_o = \frac{\text{binary input}}{2^n} \text{ V ref}$

n = # of input bits

EXAMPLE: with a binary input of $101_2 = 5_{10}$

V ref = 4 and n = 3

$$V_o = \frac{5}{8} \cdot 4 = 2.5 \text{ V}$$

(NOTE: this V_o is the resolution voltage-no smaller voltage can be produced in this care.)

D. Input coding - coding into the converter can be either binary or BCD.

(NOTE: for either input the limit for each input is 0-9 or 0000-1001.)

E. Weighted resistor converter - a convertor that uses a series of resistors to develop current from each input bit. The resistor valvue of each bit increases from left to right by doubling.

F. Multiplying D/A converters - equipment to digitally controlled potentiometers.

G. Companding D/A converter - compression/expansion converter · permits 8 bit input from a microcomputer to achieve a low signal/error over a 40 db range. The output is expressed as: $y = 0.18 \text{ hr } (1+255x)$

y = output

x = normalized input

H. Chord number - one of eight line segments which symmetrically form a linear approximation of the transfer function. Of the eight bit input, the chord represents the 3 bits: 6, 5, 4.

I. Step size - one of 16 step sizes (0-15) for the designated chord. In the eight bit input, represented by the 4 bits: 3, 2, 1, 0,

INFORMATION SHEET

J. Double buffering - used when more than 8 bits are necessary inputs for a D/A conversion. Will prevent output going to zero when lower half of input goes zero (gletch).

K. Counter A/D converter - the output of a comparator is fed to the converter that senses when the digital estimate equals or exceeds the analog input.

L. Successive approximation A/D converter - here bit-by-bit comparison is made of the comparator input which are the analog inputs voltage.

M. Parallel A/D converter - performs the comparator process simultaneously giving a digital summation. This allows continuous sampling of the analog signal.

N. Tracking A/D converter - works like a servo loop. The converter tracks the converter and locks on to it.

O. Integating A/D converter - uses an OP-amp integrator and compares the reference time to a variable time which is proportioned to the analog voltage.

P. Full scale error - known as the "gain" and is the difference in the actual from the ideal full-scale-range.

Q. Linearity - the measure of converter quality.

R. Drift - the result of variation in output as a result of temperatures.

S. Absolute accuracy - the difference between full-scale output and measured output.

T. Slew rate - the rate of change of output for large input signal changes.

U. Settling time - the time elapsed before the outputs of a D/A converter remains within its rated accuracy limits.

V. Aperture errors - the variation in input during sampling time.

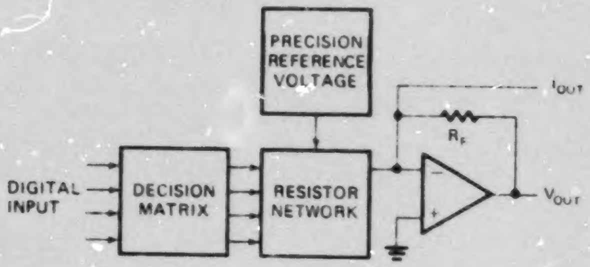
W. Sample-and-hold circuit - a circuit that freezes the input level for a specific period of time.

X. Voltage to frequency converter - a converter that changes an input voltage to a frequency proportional to the input.

INFORMATION SHEET

II. The parts of a D/A converter:

FIGURE 1


PRECISION REFERENCE VOLTAGE
DIGITAL INPUT
DECISION MATRIX
RESISTOR NETWORK
I_{OUT}
R_F
V_{OUT}
−
+

III. Types of D/A converters:

A. Multiplying

1. Has a digital and analog input.

2. Calculates output voltage by: V out = $\frac{\text{digital input}}{2^n}$ V analog

3. Classes

   a. Digital two quadrant devices have bipolar output voltages (± V).
   b. Analog two quadrant like three terminal pot.
   c. Four quadrant devices allow input and output signed to take in ± values as well as change phase by 180°.

B. Companding

1. 8 bit input is arranged:

7	6 5 4	3 2 1 0
Sig	Chord number	Step size

2. V out (step, chord) = $\frac{\text{chart (step, chord) V rep}}{2^n}$

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INFORMATION SHEET

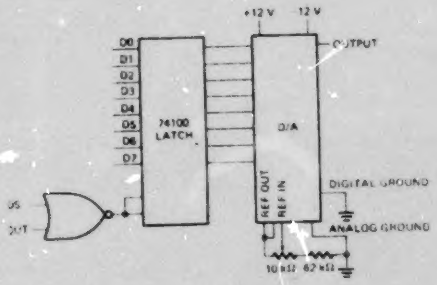
3.

Step size	Chord							
	0	1	2	3	4	5	6	7
0	0	33	99	231	495	1023	2079	4191
1	2	37	107	247	527	1087	2207	4447
2	4	41	115	263	559	1151	2335	4703
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
								maximum
15	30	93	219	471	975	1983	3999	8031
Increment	2	4	8	16	32	64	128	256
Resolution (bits)	12	11	10	9	8	7	6	5
Increment as a percent of full scale	0.025	0.05	0.1	0.2	0.4	0.8	1.6	3.2

IV. Programming D/A

A. Digital to analog interfaces

FIGURE 2


+12 V
12 V
D0
D1
D2
D3
D4
D5
D6
D7
74100 LATCH
D/A
OUTPUT
REF OUT
REF IN
DIGITAL GROUND
ANALOG GROUND
DS
OUT
10 kΩ
62 kΩ

B. Square wave generator

Square Wave Program

Label	Mnemonic	Operand	Address	Code	Comments
	MVI A	0	1000	3E	Zero the accumulator
			1001	00	
NEXT	OUT	12	1002	D3	Output the next value
			1003	12	
	LXI H	FFFF	1004	21	
			1005	FF	Loop count A HL
			1006	FF	
LOOP	DCX H		1007	2B	Decrement
	MVI A	00	1008	3E	Test for zero bit
			1009	00	
	ADD L		100A	85	
	ADD H		100B	84	
	JNZ	LOOP	100C	C2	
			100D	07	
			100E	10	
	CMA		100F	2F	Complement accumulator
	JMP	NEXT	1020	C3	
			1021	02	
			1022	10	

(NOTE: the period will be twice the delay loop. In this case it will be about 2 secs.)

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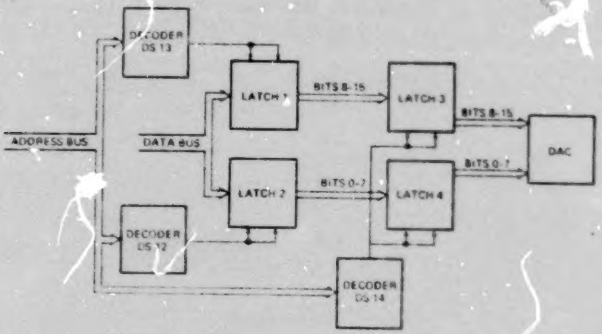
C. Sawtooth generator

Sawtooth Wave Program

Label	Mnemonic	Operand	Address	Code	Comments
NEXT	OUT	12	1000	D3	Output the next value
			1001	12	
	MVI B	7F	1002	06	Loop count → B
			1003	7F	
LOOP	DCR B		1004	05	Decrement
	JNZ	LOOP	1005	C2	Delay loop
			1006	04	
			1007	10	
	INR A		1008	3C	Increment accumulator
	JMP	NEXT	1009	C3	Repeat
			100A	00	
			100B	10	

D. Double buffering

1. For use when the input is larger than eight bit.
2. To prevent glitches the following circuit is used.
FIGURE 3


DECODER DS 13
LATCH 1
BITS 8-15
LATCH 3
BITS 8-15
ADDRESS BUS
DATA BUS
DAC
BITS 0-7
LATCH 2
BITS 0-7
LATCH 4
DECODER DS 12
DECODER DS 14

V. Types of A/D converter

A. Counter

1. A counter is used to produce the digital estimate.

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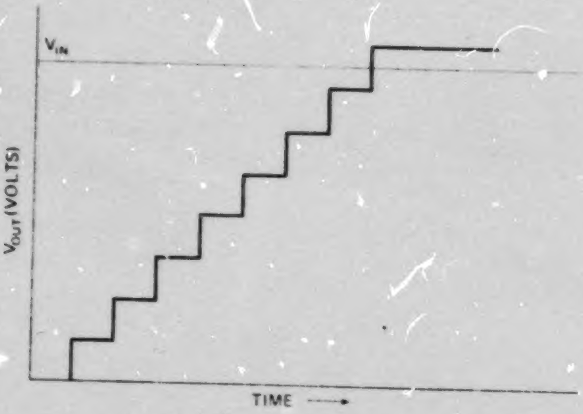
INFORMATION SHEET

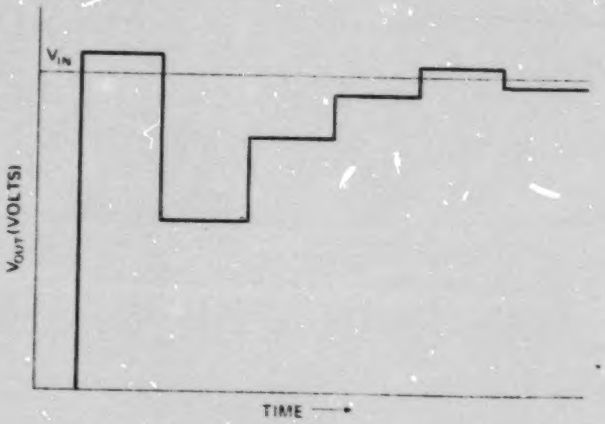
2. Simple and low cost.

FIGURE 4



B. Successive approximation

FIGURE 5



1. A good voltage reference and D/A required.
2. Conversion speeds is good (10-20 MSec)

C. Parallel

1. Used in sampling rates in excess of 10 MHz
2. Costly

D. Tracking

1. Works on servo principle
2. Very accurate though large time lag for large input jumps

INFORMATION SHEET

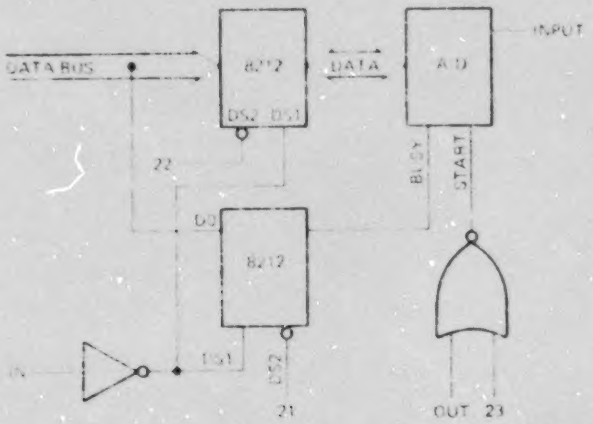
E. Integrating

1. Insensitive to component valves

2. Main disadvantage is slow conversion time

VI. Sample A/D circuit

FIGURE 6


DATA BUS
8212
DS2
DS1
DATA
A/D
INPUT
22
BUSY
START
D0
8212
IN
DS1
DS2
21
OUT
23

A/D Conversion Program

Label	Mnemonic	Operand	Address	Code	Comments
	OUT	23	1000	D3	Start conversion
			1001	23	
LOOP	IN	21	1002	DB	Input $\overline{\text{BUSY}}$
			1003	21	
	ANI	01	1004	E6	Get bit 0
			1005	01	
	JZ	LOOP	1006	CA	If still busy, check again
			1007	02	
			1008	10	
	IN	22	1009	DB	Sample A/D converter output
			100A	22	

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VII. Data Encryption Unit (DEU)

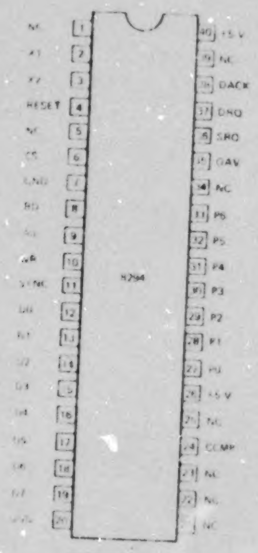
A. A device that is based on a reversible algorithum that uses a large number of math transforms that scramble, or encrypt, the original bit sequence. The encryption cannot be broken without the key.

B. The procedure required 16 rounds of key controller sustitutions and permutations.

C. Coding groups 8 bytes into 64 bit data blocks; then operates on that block as a unit.

D. The 8294 data encryption unit will do the necessary coding.

FIGURE 7


NC
X1
X2
RESET
NC
CS
GND
RD
A0
WR
SYNC
D0
D1
D2
D3
D4
D5
D6
D7
VSS
8294
+5 V
NC
DACK
DRQ
SRQ
OAV
NC
P6
P5
P4
P3
P2
P1
P0
+5 V
NC
CCMP
NC
NC
NC

Data Encryption Unit Signals

Signal name	Purpose	Input or output
D0 D7	Data bus	Bidirectional
RD	Read strobe	Input
WR	Write strobe	Input
A0	Control/data select	Input
RESET	Initialization	Input
X1, X2	Frequency reference	Input
SYNC	High frequency	Output
DRQ	DMA request	Input
DACK	DMA acknowledge	Output
SRQ, OAV, CCMP	Interrupt requests	Output
P0 P6	Output port	Output
CS	Chip select	Input

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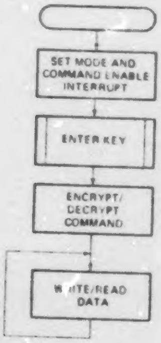
E. Pin usage

1. Timing - provided by external crystal through X1 or X2 (input).
2. Enabling - for reading and writing with the $\overline{\text{CS}}$ (input).
3. Idle - when $\overline{\text{RESET}}$ goes low (input).
4. Sync - a frequency equal to the clock divided by 15 (output).
5. To move data into use DRQ (input) from a DMA and $\overline{\text{DACH}}$ (output).
6. To inform the processor the 8294 is awaiting data the SRQ (output) is used.
7. When data or status is ready for output use the DAV (output).
8. CCMP (output) is available after a 64 bit block has been encrypted.
9. The data output pin or PO-P6 (7 bits)
10. To program the unit, the flowchart in figure must be followed:

FIGURE 8


SET MODE AND COMMAND ENABLE INTERRUPT
ENTER KEY
ENCRYPT/ DECRYPT COMMAND
WRITE/READ DATA

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INFORMATION SHEET

F. Encryption procedure

1. Command input buffer receives instruction as listed below.

Data Encryption Unit Commands

Command	Function
40	Enter new key. Followed by 8-byte key (each key byte must have odd parity using LSB).
30	Encrypt data.
20	Decrypt data.
0X	Set mode, enable interrupts, or allow DMA transfers for value of X. 0 none 1 CCMP 2 DMA 3 DMA, CCMP 4 SRQ 5 SRQ, CCMP 6 SRQ, DMA 7 SRQ, DMA, CCMP 8 OAV 9 OAV, CCMP A OAV, DMA B OAV, DMA, CCMP C OAV, SRQ D OAV, SRQ, CCMP E OAV, SRQ, DMA F all
*Various	Write to output port. (MSB* of command must be a 1, remaining bits are output on P6–P0, respectively.)

2. When a key is entered, it must be preceded by the appropriate command. The MSB is entered first.

3. Encrypt or decrypt mode is selected.

4. Reading of registers is controlled by four pins as seen below:

Accessing Registers

Register	Signal			
	RD	WR	CS	A0
Data input buffer	1	0	0	0
Data output buffer	0	1	0	0
Command input buffer	1	0	0	1
Status output buffer	0	1	0	1

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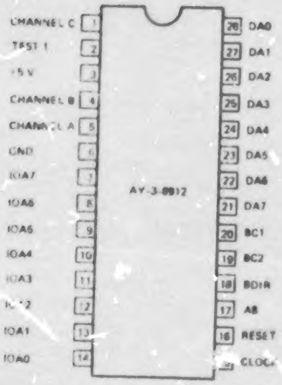
FIGURE 11


CHANNEL C
TEST 1
+5 V
CHANNEL B
CHANNEL A
GND
IOA7
IOA6
IOA5
IOA4
IOA3
IOA2
IOA1
IOA0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
AY-3-8912
28
27
26
25
24
23
22
21
20
19
18
17
16
15
DA0
DA1
DA2
DA3
DA4
DA5
DA6
DA7
BC1
BC2
BDIR
A8
RESET
CLOCK

Sound Generator Signals

Signal	Purpose	Input or Output
DA0-DA7	Data and address bus	Bidirectional
A8	Upper address bit	Input
RESET	Power-on initialization	Input
CLOCK	Timing reference	Input
BDIR, BC1, BC2	Bus control	Input
Analog channels A, B, C	Sound signal	Output
IOA0-IOA7	I/O port	Bidirectional
TEST 1, 2	Not used	

B. This IC has its own D/A converter and provides programmed control of frequency and amplitude of three tones.

C. Pin usage

1. Bidirectional data buses passes data (DA1-DA7) and address information.

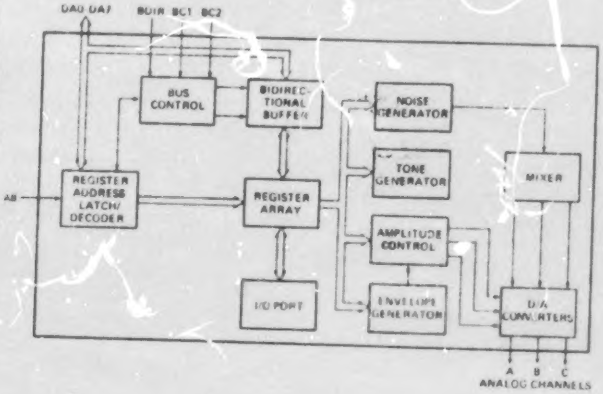
2. $\overline{\text{RESET}}$ low provides an idle condition (input).

3. CLOCK requires a TTL compatible oscillator (input).

4. Channel A, B, C provides the output for each tone.

5. The audio regional is produced as shown in the following block diagram.

FIGURE 12


DA0-DA7
BDIR
BC1
BC2
BUS CONTROL
BIDIRECTIONAL BUFFER
NOISE GENERATOR
TONE GENERATOR
MIXER
A8
REGISTER ADDRESS LATCH/ DECODER
REGISTER ARRAY
AMPLITUDE CONTROL
I/O PORT
ENVELOPE GENERATOR
D/A CONVERTERS
A
B
C
ANALOG CHANNELS

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6. Control registers

Register Usage

Register	Function
0	Channel A
1	Tone period
2	Channel B
3	Tone period
4	Channel C
5	Tone period
6	Noise period
7	Enable
8	Channel A amplifier
9	Channel B amplifier
10	Channel C amplifier
11	Envelope period
12	
13	Envelope shape
14	I/O port buffer
15	Not used

- a. The registers are used as listed in the table above.
- b. 0-5 tone
- c. 6 noise
- d. 7 enable
- e. 8-10 amplifiers
- f. 11-13 envelope period and shape
- g. 14 I/O part buff.

D. Tone generation - dependent on oscillator clock frequency input:

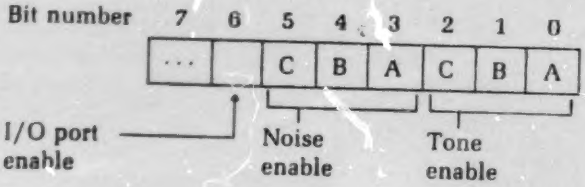
$$f_{tone} = \frac{f\ clock}{16\ (TP)}$$

TP = 12 bits from tone period register

E. Noise generator - $f_{none} = \frac{f\ clock}{16\ (NP)}$

NP = lower 5 bits of register 6

F. Mixer control - this control is provided by R7



G. Amplitude

1. Provided by registers R8 - R10

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2. Can be fixed (channel 4 zero)

3. Can be variable (channel 4 1)

4. Lowers 4 bits specify level (F_{16} = max)

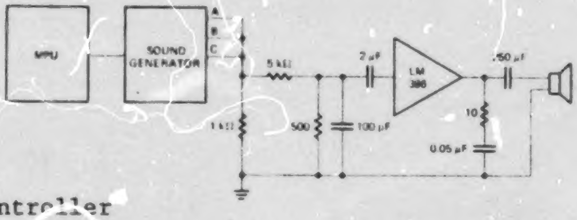
H. Envelope control - allows complex sounds to be produced

$$f_{env} = \frac{f\ clock}{256\ (TE)}$$

TE = 16 bits from R11 and R12

I. A sample circuit is shown below:

FIGURE 13

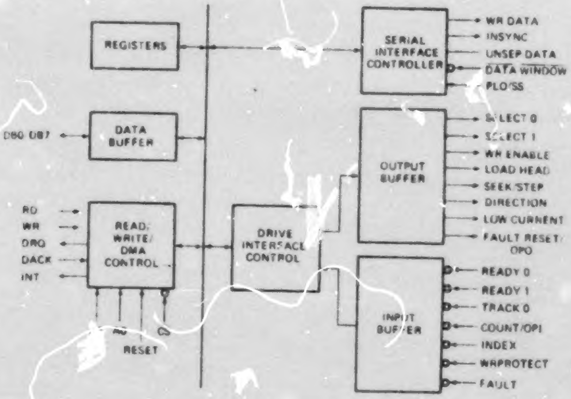

MPU
SOUND GENERATOR
A
B
C
5 kΩ
1 kΩ
500
100 μF
2 μF
LM 386
50 μF
10
0.05 μF

IX. Floppy-disk controller

A. The INTEL 8271 can read, write, or scan a disk for a specific bit pattern.

B. The block diagram for the INTEL 8271 is below:

FIGURE 14


REGISTERS
DATA BUFFER
DB0 DB7
RD
WR
DRQ
DACK
INT
READ/ WRITE/ DMA CONTROL
A0
CS
RESET
DRIVE INTERFACE CONTROL
SERIAL INTERFACE CONTROLLER
WR DATA
INSYNC
UNSEP DATA
DATA WINDOW
PLO/SS
OUTPUT BUFFER
SELECT 0
SELECT 1
WR ENABLE
LOAD HEAD
SEEK/STEP
DIRECTION
LOW CURRENT
FAULT RESET/ OPO
INPUT BUFFER
READY 0
READY 1
TRACK 0
COUNT/OPI
INDEX
WRPROTECT
FAULT

(NOTE: The data buffer supports the 8-bit data bus input and output. ADMA controller is supplied to fetch or store data from memory.)

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C. Pin description is shown in the table below:

Floppy Disk Controller Signals

Name	Function	Direction
DB0-DB7	Three-state data bus	Bidirectional
RESET	Select idle state	Input
CS	Chip select	Input
A0-A1	Interface register select	Input
INT	Service request interrupt	Output
DRQ	DMA request	Output
DACK	DMA acknowledge	Input
WR	Write command	Input
RD	Read command	Input
WR DATA	Write disk data	Output
INSYNC	Input data sync has been achieved	Output
UNSEP DATA	Unseparated data (the combined clock and data input)	Input
DATA WINDOW	Data window established	Input
PLO/SS	Data separator specifier	Input
SELECT 0, SELECT 1	Drive select	Output
WR ENABLE	Write enable	Output
LOAD HEAD	Signal drive to press the head against the disk	Output
SEEK/STEP	Seek control	Output
DIRECTION	Seek direction (high means inward, low means outward)	Output
LOW CURRENT	Track 43 or higher selected	Output
FAULT RESET/OPO	Error condition reset	Output
READY 0, READY 1	Specified drive ready	Input
TRACK 0	Head is positioned over track 00	Input
COUNT/OPI	Stepping pulse	Input
INDEX	Disk index position	Input
WR PROTECT	Disk is write protected	Input
FAULT	Unsafe condition	Input

D. Operating information

1. Transfer of data is usually by DMA but not required. A byte can be sent in 32 M sec.

2. Drive commands rely on clock impulse to reconstruct input bits.

3. In writing data, the controller builds the composite data block by interweaving clock pulses with date bits.

4. ID and CRC field identification is completed for each field and the codes attached to the field.

5. With WR ENABLE high data is passed to the write load. A low causes the loads to read.

6. To initialize the drive, the controller pulses the seek/step high and the direction line for desired movement.

7. The track steps in or out one track for every seek/step pulse.

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8. Head seeking time can be programmed to be from 0 to 255 MS for 8 in drives and 510 MS for minidrives.

9. When faults are sensed (ex. $\overline{\text{WRPROTECT}}$) interrupts are initiated.

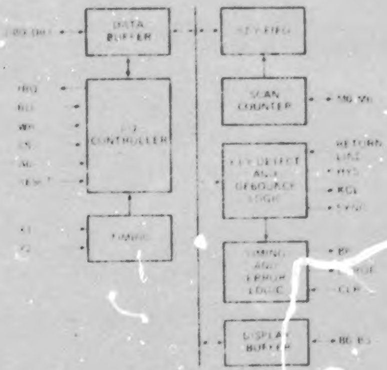
10. To send a command the status register is checked to insure the command busy bit is not set.

11. After an operation, the command byte is examined for successful results.

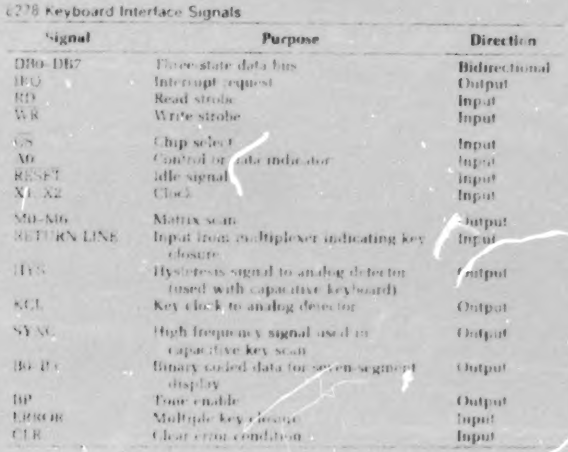
X. Keyboard controller

A. A block diagram for the INTEL 8278 is shown below:

FIGURE 15


DATA BUFFER
KEY FIFO
SCAN COUNTER
CONTROLLER
KEY DETECT AND DEBOUNCE LOGIC
TIMING
TIMING AND ERROR LOGIC
DISPLAY BUFFER
RETURN LINE
HYS
KCL
SYNC
BP
CLR

B. A description of the commands:



8278 Keyboard Interface Signals

Signal	Purpose	Direction
DB0-DB7	Three-state data bus	Bidirectional
IRQ	Interrupt request	Output
RD	Read strobe	Input
WR	Write strobe	Input
CS	Chip select	Input
A0	Control or data indicator	Input
RESET	Idle signal	Input
X1, X2	Clock	Input
M0-M6	Matrix scan	Output
RETURN LINE	Input from multiplexer indicating key closure	Input
HYS	Hysteresis signal to analog detector (used with capacitive keyboard)	Output
KCL	Key click to analog detector	Output
SYNC	High frequency signal used in capacitive key scan	Output
B0-B3	Binary coded data for seven-segment display	Output
BP	Tone enable	Output
ERROR	Multiple key closure	Input
CLR	Clear error condition	Input

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C. This circuit can scan a 128 key keyboard arranged in 16 columns by 8 rows and a multiple - digit LED display.

D. Scan counter, key detect and FIFO detect when a key is depressed and save the position until it can be passed to the processor.

E. The scan counter looks like:

SF	M6	M5	M4	M3	M2	M1	M0
Special function key	columns				rows		

The output converted to one of 16 lines using a 4-to-16 decoder.

F. Debouncing is incorporated.

G. FIFO buffer is 8 bytes long allowing a series of key depressions to be saved.

XI. CRT controller

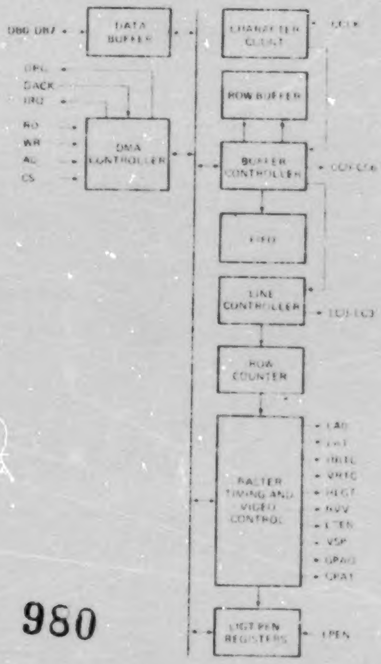
A. The 8275 CRT controller

1. Has a DMA controller for the interface.

2. Has a data buffer for the interface.

B. A block diagram of the 8275:

FIGURE 16


DATA BUFFER
DACK
RD
WR
CS
DMA CONTROLLER
ROW BUFFER
BUFFER CONTROLLER
FIFO
LINE CONTROLLER
ROW COUNTER
RASTER TIMING AND VIDEO CONTROL
VSP
LIGHT PEN REGISTERS
LPEN

INFORMATION SHEET

C. Row-by-row retrieval from memory is utilized.

D. Character counter determines the number of characters to be written on a row.

E. Line counter maintains the horizontal lines in a row.

F. The display format is under program control 1 to 80 in a row and up to 64 rows in a display.

G. To draw a character 1 to 16 lines can be used.

H. To produce video sync and intensity voltage require a character generator and dot timing interface.

I. To select position on the screen, line counter and character codes are used.

J. Dot timing logic supplies a clock to synchronize all devices.

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ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

LAB SHEET #1 - D/A INTERFACING

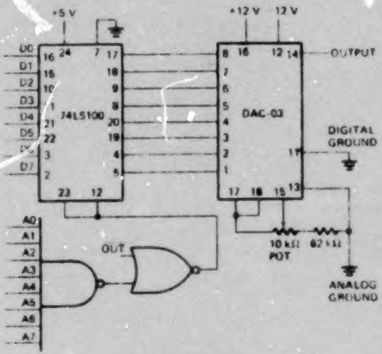
I. Equipment

A. 1 - PM DAC-03
B. 1 - 74LS02
C. 1 - 74LS03
D. 1 - 74LS100
E. 1 - 10K potentiometer
F. 1 - 62K resistor
G. Power supply (+5V, ± 12V)
H. Oscilloscope
I. Microcomputer
J. Hook-up wire

II. Procedure

A. Wire the circuit in Figure 1.

FIGURE 1


+5 V
24
7
D0
D1
D2
D3
D4
D5
D6
D7
16
15
10
1
21
22
3
2
74LS100
17
18
9
8
20
19
4
5
23
12
+12 V
12 V
8
16
12
14
OUTPUT
7
6
5
4
3
2
1
DAC-03
DIGITAL
GROUND
11
17
18
15
13
10 kΩ
POT
62 kΩ
ANALOG
GROUND
A0
A1
A2
A3
A4
A5
A6
A7
OUT

B. Turn on the power supply.

C. Load the following program into the MC.

Address	Code
1000	3E
1001	FF
1002	D3
1003	FF
1004	C3
1005	02
1006	10

(NOTE: the device address is FF_{16}.)

D. Execute the program which outputs a full scale value.

LAB SHEET #1 - D/A INTERFACING

E. While the program is running, adjust the pot for a 5V output on the D/A converter.

F. Load the program listed in the Information Sheet under "Item IV, B".

G. Execute the program. What pattern do you observe on the oscilloscope?________________________________

H. Now load the program listed in the Information Sheet under "Item IV, C".

I. Execute the program. What pattern do you observe on the oscilloscope?________________________________

J. Now write your own program to produce a square wave that has its output high half as long a time as it is low.

K. Load and execute the program.

(NOTE: Show your results to the instructor.)

L. Turn off the power.

M. Put up your equipment

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ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

LAB SHEET #2 - USING THE DAC-03

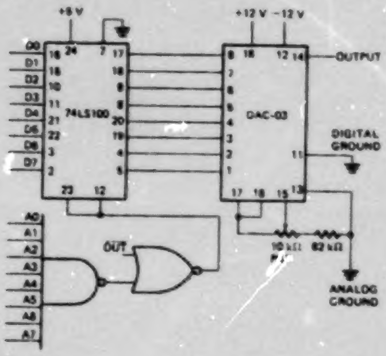
I. Equipment

A. 1-74LS02
B. 1-74LS30
C. 1-74LS100
D. 1-DAC-03
E. 1-10KΩ potentiometer
F. 1-62KΩ resistor
G. +5 V and ∓ 12 V power supply
H. Oscilloscope
I. Microcomputer

II. Procedure

A. Connect the circuit shown in Figure 1.

FIGURE 1


+5 V
+12 V
-12 V
D0
D1
D2
D3
D4
D5
D6
D7
74LS100
DAC-03
OUTPUT
DIGITAL GROUND
A0
A1
A2
A3
A4
A5
A6
A7
$\overline{OUT}$
10 kΩ
82 kΩ
ANALOG GROUND

B. Load the program listed below.

Label	Mnemonic	Operand	Address	Code	Comments
	MVI A	FF	1000	3E	All 1s A
			1001	FF	
LOOP	OUT	FF	1002	D3	Output on port FF
			1003	FF	
	JMP	LOOP	1004	C3	Repeat
			1005	02	
			1006	10	

LAB SHEET #2

C. Execute the program and while it is running, adjust the output for a 5 volt output on the DAC-03.

D. Now load the square wave program (Table 1) and observe the pattern on the oscilloscope.

TABLE 1

Square Wave Program

Label	Mnemonic	Operand	Address	Code	Comments
	MVI A	0	1000	3E	Zero the accumulator
			1001	00	
NEXT	OUT	12	1002	D3	Output the next value
			1003	12	
	LXI H	FFFF	1004	21	
			1005	FF	Loop count A HI
			1006	FF	
LOOP	DCX H		1007	2B	Decrement
	MVI A	00	1008	3E	Test for zero bit
			1009	00	
	ADD L		100A	85	
	ADD H		100B	84	
	JNZ	LOOP	100C	C2	
			100D	07	
			100E	10	
	CMA		100F	2F	Complement accumulator
	JMP	NEXT	1020	C3	
			1021	02	
			1022	10	

E. Now load the sawtooth program (Table 2) and observe the pattern on the oscilloscope.

F. Write your own program to generate a square wave that has its output high half as long a time as it is low.

G. Run your program. Have your instructor observe your square wave pattern.

H. Put up your equipment.

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ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

LAB SHEET #3 - TEST PARALLEL INPUT PROGRAMS FOR THE 7522

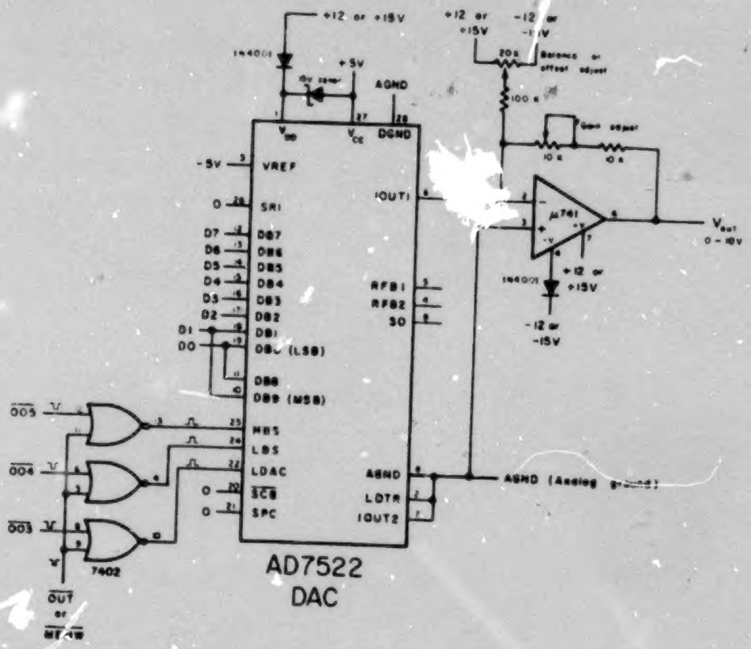
I. Equipment

A. 1-7522 DAC
B. 1-74LS02
C. 2-IN4001
D. 1-Zenerdiode
E. 1-20KΩ potentiometer
F. 1-10KΩ potentiometer
G. 1-10KΩ resistor
H. 1-VOM

II. Procedures

A. Connect the circuit shown in Figure 1.

FIGURE 1


+12 or +15V
1N4001
10v zener
+5V
AGND
+12 or +15V
-12 or -15V
20k
Balance or offset adjust
100 k
Gain adjust
10 k
10 k
1
27
28
VDD
VCC
DGND
-5V
3
VREF
0
SRI
D7
D6
D5
D4
D3
D2
D1
D0
DB7
DB6
DB5
DB4
DB3
DB2
DB1
DB0 (LSB)
DB8
DB9 (MSB)
IOUT1
μ741
Vout
0 - 10V
RFB1
RFB2
SO
1N4001
+12 or +15V
-12 or -15V
$\overline{005}$
$\overline{004}$
$\overline{003}$
MBS
LBS
LDAC
$\overline{SCB}$
SPC
AGND
LDTR
IOUT2
AGND (Analog ground)
7402
$\overline{OUT}$
or
$\overline{MEMW}$
AD7522
DAC

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LAB SHEET #3

B. Load the program listed below:

LO Memory Address	Octal Instruction		Mnemonic	Comments
000	042	START,	SHLD	Strobe ten bits of digital data into the AD7522 DAC registers
001	004		004	HI = 000 and LO = 004 is the memory I/O device code for the LBS input to the DAC. HI = 000 and LO = 005 is the memory I/O device code for the HBS input to the DAC. [NOTE: We can use these device codes since memory block HI = 000 is EPROM.]
002	000		000	
003	062		STA	Send strobe pulse to the LDAC input of the AD7522 DAC. Ten bits of digital data are internally strobed within the DAC into the DAC register.
004	003		003	HI = 000 and LO = 003 is the memory I/O device code for the LDAC input to the DAC
055	000		000	
006	043		INX H	Increment register pair H
007	315		CALL	Call 10 ms time-delay routine located in the KEX EPROM (memory block HI = 000)
010	277		TIMEOUT	LO address byte of TIMEOUT
011	000		—	HI address byte of TIMEOUT
012	303		JMP	Jump back to START and repeat the execution of the program
013	000		START	LO address byte of START
014	003		—	HI address byte of START

LO Memory Address	Octal Instruction		Mnemonic	Comments
277	365	TIMEOUT,	PUSH PSW	Push contents of accumulator and flags on stack
300	325		PUSH D	Push contents of register pair D on stack
301	021		LXI D	Load following two bytes into register pair D
302	046		046	E register byte
303	001		001	D register byte
304	033	MORE,	DCX D	Decrement contents of register pair D by one
305	172		MOV A,D	Move contents of register D to accumulator
306	263		ORA E	OR contents of register E with contents of accumulator
307	302		JNZ	Jump to LOOP if result of OR operation is not 000; otherwise, skip this instruction after testing the zero flag
310	304		MORE	LO address byte of MORE
311	000		—	HI address byte of MORE
312	321		POP D	Pop stack into register pair D
313	341		POP PSW	Pop stack into accumulator and flags
314	311		RET	Return from subroutine

(NOTE: These programs are written in octal.)

LAB SHEET #3

C. Connect the VOM to the DAC output and execute the program. What do you observe?

D. You should see a continuous repeating VOM reading to +5.6 volts.

E. Change the instruction at 006 to 006 053 DCX H (decrement register pair H). Execute the program again. What do you observe this time?

F. You should see a continuous repeating VOM reading decreasing from +5.6 volts to 0 volts.

LAB SHEET #3

G. Now NOP words 007, 010, 011. Execute the program and describe what you see.

____

____

____

____

H. This time you should see an oscillating voltage reading about +2.75 volts.

I. Show your answers and setup to your instructor.

J. Put up your equipment or save the set-up for the next experiment.

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

LAB SHEET #4 - USING A DAC-03 FOR ANALOG TO DIGITAL CONVERSION

I. Equipment

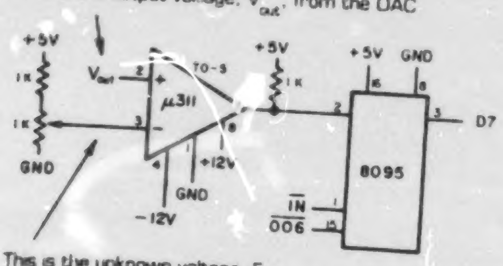
A. 1-7522 DAC
B. 1-74LS02
C. 2-IN4001
D. 1-Zenerdiode
E. 1-20KΩ potentiometer
F. 1-10KΩ potentiometer
G. 1-10KΩ resistor
H. 1-VOM
I. 1-LM311 comparator
J. 1-8095
K. 3-1KΩ resistor
L. 1-1KΩ potentiometer
M. A digital voltmeter may be used in place of the VOM

II. Procedure

A. If the set-up from the previous experiment has been put away, reconstruct it now.

B. Add to the wiring in Step A, the wiring in Figure 1 below.

FIGURE 1



This is the output voltage, V_{out}, from the DAC

This is the unknown voltage, E

+5V
1K
1K
GND
V_{out}
2
3
+
−
μ311
TO-5
4
1
8
7
+12V
GND
−12V
+5V
1K
+5V
GND
16
8
2
3
D7
8095
$\overline{IN}$
$\overline{OO6}$
1
15

LAB SHEET #4

C. Now load the following program.

LO Memory Address	Instruction Byte			Mnemonic	Description
123	062	32		STA	Send strobe pulse to LDAC input of AD7522 DAC; load data into DAC register
124	003	03		003	HI = 000 and LO = 003 is memory I/O device code for LDAC input
125	000	00		000	
126	043	23		INX H	Increment register pair H
127	333	DB		IN	Input into bit D7 the output from the AD311 comparator
130	006	06		006	Device code for comparator bit
131	346	E6		ANI	Mask all bits in accumulator except bit D7
132	200	80		200	Mask Byte
133	312	CA		JZ	If comparator, bit D7, is logic 1, continue to steps below; otherwise, jump to AGAIN and continue to increment the DAC output
134	120*	50*		AGAIN	LO address byte of AGAIN
135	001*	01*		—	HI address byte of AGAIN
136	175	7D		MOV A,L	Move the low eight bits of the DAC word to the accumulator
137	323	D3		OUT	Output low eight bits of DAC word to following output port
140	002	02		002	Device code for output port 002
141	174	7C		MOV A,H	Move the high two bits of the DAC word to the accumulator
142	323	D3		OUT	Output high two bits of DAC word to following output port
143	002	02		000	Device code for output port 002
144	361	F1		POP PSW	Pop accumulator and flags off stack
145	341	E1		POP H	Pop register pair H off stack
146	321	D1		POP D	Pop register pair D off stack
147	301	C1		POP B	Pop register pair B off stack
150	311	C9		RET	Return from subroutine
107	305	C5	CONVRT,	PUSH B	Push contents of register pair B on stack
110	325	D5		PUSH D	Push register pair D on stack
111	345	E5		PUSH H	Push register pair H on stack
112	365	F5		PUSH PSW	Push accumulator and flags on stack
113	323	D3		OUT	Generate synchronization pulse
114	007	07		007	Device code of synchronization pulse
115	041	21		LXI H	Initialize register pair H
116	000	00		000	L register byte
117	000	00		000	H register byte
120	042	22	AGAIN,	SHLD	Strobe ten bits of digital data into the AD7522 DAC shift registers
121	004	04		004	HI = 000 and LO = 004 is memory I/O device code for LBS input; HI = 000 and LO = 005 is memory I/O device code for HBS input.
122	000	00		000	

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LAB SHEET #4

D. Connect the VOM. The program will permit a single conversion and then halt. The analog voltage will be on the VOM and the digital equivalent will be at the two output ports.

E. Execute the program with the 1KΩ potentiometer set at 0Ω. What did you observe?

F. A reading of 0.0 volt should appear on the VOM. Now, set the 1KΩ pot. to its maximum value. What output do you observe on the VOM and DAC?

G. You should have observed approximately +2.3 volts on the VOM and a 1 and 371 on the output ports of the DAC.

H. Now select different settings for the 1K pot and record various readings and observations.

I. Show your observations to your instructor.

J. Put up your equipment.

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV
TEST

NAME____SCORE:__________

1. Match terms associated with A/O and D/A interfaces to their correct definitions. Write the correct numbers in the blanks.

_____a. Equipment to digitally controlled potentiometers.

_____b. Compression/expansion converter permits 8 bit input from a microcomputer to achieve a low signal/error over a 40 db range.

_____c. One of 16 step sizes (0-15) for the designated chord.

_____d. Coding into the converter can be either binary or BCD.

_____e. Output range voltage.

_____f. Used when more than 8 bits are necessary inputs for a D/A conversion.

_____g. The result of variation in output as a result of temperatures.

_____h. A converter that changes an input voltage to a frequency proportional to the input.

_____i. One of eight line segments which symmetrically form a linear approximation of the transfer function.

_____j. A circuit that freezes the input level for a specific period of time.

_____k. The time elapsed before the outputs of a D/A converter remains within its rated accuracy limits.

_____l. The variation in input during sampling time.

_____m. Performs the comparator process simultaneously giving a digital summation.

_____n. A converter that uses a series of resistors to develop current from each input bit.

1. Sample-and-hold circuit
2. Settling time
3. Absolute accuracy
4. Double buggering
5. Parallel A/D converter
6. Linearity
7. Multiplying D/A converters
8. Weighted resistor converter
9. Decision matrix
10. Aperture errors
11. Voltage to frequency converter
12. Slew rate
13. Counter A/D converter
14. Companding D/A converter
15. Input coding
16. Step size
17. Precision reference voltage
18. Chord number

TEST

_____o. Uses an OP-amp integrator and compares the reference time to a variable time which is proportioned to the analog voltage.

_____p. Works like a servo loop.

_____q. Here bit-by-bit comparison is made of the comparator input which are the analog inputs voltage.

_____r. The output of a comparator is fed to the converter that senses when the digital estimate equals or exceeds the analog input.

_____s. Known as the "gain" and is the difference in the actual from the ideal full-scale-range.

_____t. The difference between full-scale output and measured output.

_____u. The rate of change of output for large input signal changes.

_____v. A collection of logic gates in a D/A counter to which digital inputs are applied.

_____w. The voltage which is the source of the drive for the resistor network in a D/A converter.

_____x. The measure of converter quality.

19. $V_o = \frac{\text{binary input}}{2^n} V \text{ ref}$

20. Successive approximation A/D converter

21. Tracking A/D converter

22. Full scale error

23. Integating A/D converter

24. Drift

2. List the parts of a D/A converter.

   a.

   b.

   c.

   d.

3. Name two types of D/A converters.

   a.

   b.

TEST

4. Discuss the need for a programmable converter.

5. Name five types of A/D converters.

a.

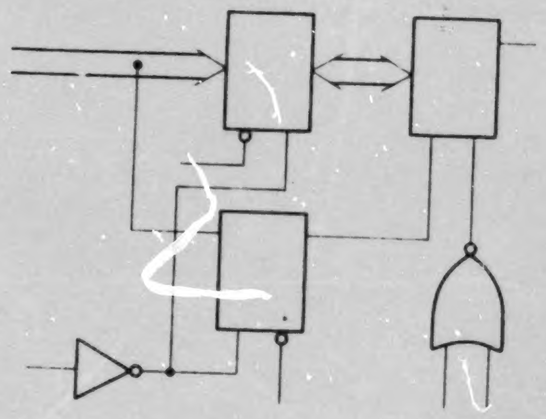
b.

c.

d.

e.

6. Label the parts of the following A/D circuit.



TEST

7. Construct an encryption and decryption flowchart for the data encryption unit.

8. Draw a sound generator block diagram.

TEST

9. Draw a floppy-disk controller block diagram.

10. Draw a keyboard controller block diagram.

TEST

11. Draw a CRT controller block diagram.

(NOTE: Test question 12 relates to lab sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

12. Demonstrate the ability to

    a. Use the DAC-03 D/A converter

    b. Test parallel input programs for the 7522 DAC

    c. Use a DAC-03 for A/D conversion

13. End of test. STOP! Have your instructor evaluate your test. If you receive a score of 80 percent or more, continue to the next unit. If additional study is necessary, ask your instructor about study requirements and possible retesting.

ANALOG/DIGITAL INTERFACES AND PERIPHERAL EQUIPMENT

UNIT IV

TEST ANSWERS

1. a. 7
   b. 14
   c. 16
   d. 15
   e. 19
   f. 4
   g. 24
   h. 11
   i. 18
   j. 1
   k. 2
   l. 10
   m. 5
   n. 8
   o. 23
   p. 21
   q. 20
   r. 13
   s. 22
   t. 3
   u. 12
   v. 9
   w. 17
   x. 6

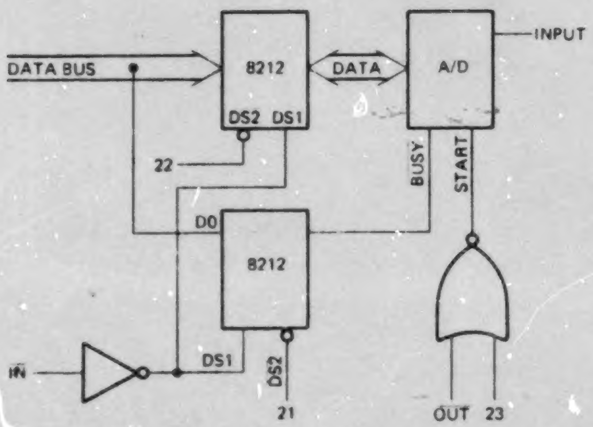
2. a. Decision matrix
   b. Voltage reference
   c. Resistor network
   d. OP amp

3. Multiplying
   Companding

4. Being able to change the program in a computer allows the same circuit to be used for many different waveforms.

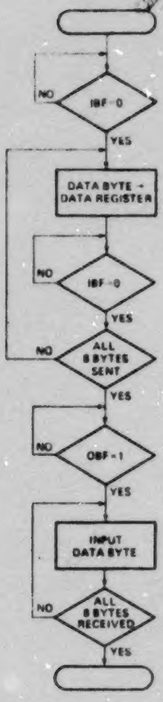
5. a. Counter
   b. Successive approximation
   c. Parallel
   d. Tracking
   e. Integrating

6.

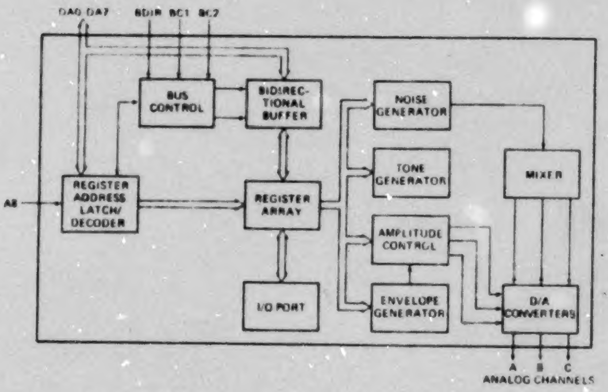

INPUT
DATA BUS
8212
DATA
A/D
DS2
DS1
22
BUSY
START
D0
8212
$\overline{\text{IN}}$
DS1
DS2
21
OUT
23

TEST ANSWERS

7.


NO
IBF=0
YES
DATA BYTE → DATA REGISTER
NO
IBF=0
YES
NO
ALL 8 BYTES SENT
YES
NO
OBF=1
YES
INPUT DATA BYTE
NO
ALL 8 BYTES RECEIVED
YES

8.


DA0-DA7
BDIR
BC1
BC2
BUS CONTROL
BIDIRECTIONAL BUFFER
NOISE GENERATOR
TONE GENERATOR
MIXER
A8
REGISTER ADDRESS LATCH/ DECODER
REGISTER ARRAY
AMPLITUDE CONTROL
ENVELOPE GENERATOR
I/O PORT
D/A CONVERTERS
A
B
C
ANALOG CHANNELS

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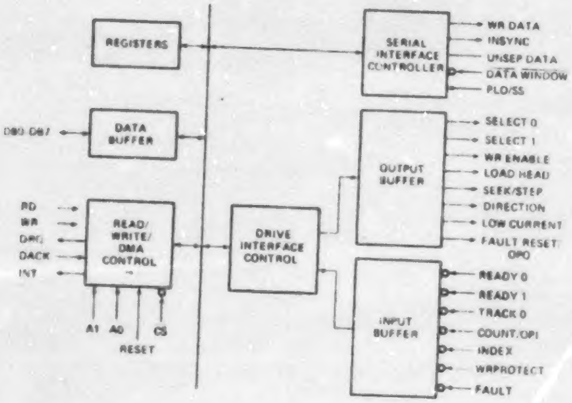
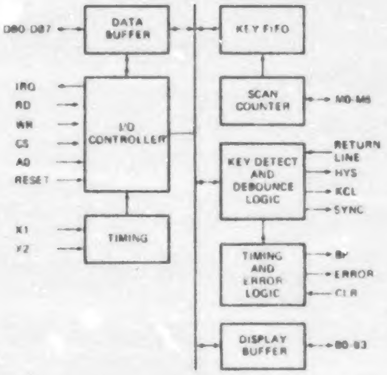
TEST ANSWERS

9.


REGISTERS
DATA BUFFER
DB0-DB7
RD
WR
DRQ
DACK
INT
READ/ WRITE/ DMA CONTROL
A1
A0
RESET
CS
DRIVE INTERFACE CONTROL
SERIAL INTERFACE CONTROLLER
WR DATA
INSYNC
UNSEP DATA
DATA WINDOW
PLO/SS
OUTPUT BUFFER
SELECT 0
SELECT 1
WR ENABLE
LOAD HEAD
SEEK/STEP
DIRECTION
LOW CURRENT
FAULT RESET OPO
INPUT BUFFER
READY 0
READY 1
TRACK 0
COUNT/OPI
INDEX
WRPROTECT
FAULT

10.


DB0-DB7
DATA BUFFER
IRQ
RD
WR
CS
A0
RESET
I/O CONTROLLER
X1
X2
TIMING
KEY FIFO
SCAN COUNTER
M0-M6
KEY DETECT AND DEBOUNCE LOGIC
RETURN LINE
HYS
KCL
SYNC
TIMING AND ERROR LOGIC
BY
ERROR
CLR
DISPLAY BUFFER
B0-B3

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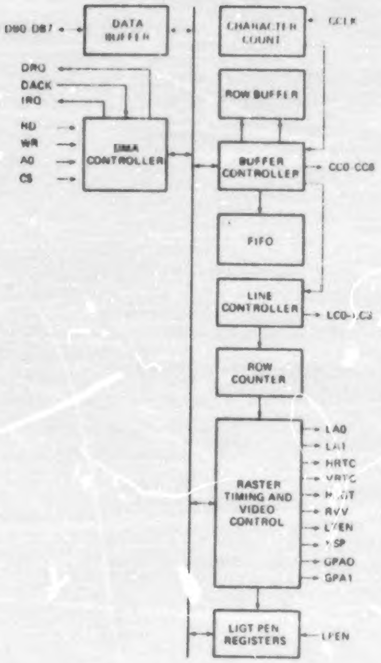
TEST ANSWERS

11.


DB0-DB7
DATA BUFFER
CHARACTER COUNT
CCLK
DRQ
DACK
IRQ
RD
WR
A0
CS
DMA CONTROLLER
ROW BUFFER
BUFFER CONTROLLER
CC0-CC6
FIFO
LINE CONTROLLER
LC0-LC3
ROW COUNTER
RASTER TIMING AND VIDEO CONTROL
LA0
LA1
HRTC
VRTC
HLGT
RVV
LTEN
VSP
GPA0
GPA1
LIGT PEN REGISTERS
LPEN

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MICROPROCESSOR AND INTERFACING

UNIT V

TROUBLESHOOTING MICROPROCESSOR

TROUBLESHOOTING MICROPROCESSORS

UNIT V

OBJECTIVE

After completing this unit, the student should be able to troubleshoot a microcomputer. This knowledge will be shown by completing lab sheets and unit test with a minimum score of 80 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match the terms associated with troubleshooting to their correct definitions.
2. List ordered steps to properly troubleshoot a microcomputer.

TROUBLESHOOTING MICROPROCESSORS

UNIT V

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Provide students with information sheets.

   C. Discuss unit and specific objectives.

   D. Discuss information sheets.

   E. Demonstrate several pre-bugged microprocessor.

   F. Lead students as a group to troubleshoot "pre-bugged" microcomputing system.

   G. Give test.

II. Student

   A. Read objective sheet.

   B. Study information sheet.

   C. Participate as a class in troubleshooting system.

   D. Take test.

TROUBLESHOOTING MICROPROCESSORS

UNIT V

INSTRUCTIONAL MATERIAL

I. Included in this unit:

A. Objective sheet.

B. Information sheets.

C. Test.

II. References

A. Pasahow, Edward J., Microprocessors and Microcomputer, New York, New York, McGraw-Hill Book Co., 1981.

B. Camp, Smay, Triska, Microprocessor Systems Engineering, Beaverton, Oregon, Matrix Publishers, 1979.

C. Rony, Peter R., Introductory Experiments in Digital Electronic and 8080A Microcomputer Programming and Interfacing VI, Indianapolis, Indiana, Howard W. Sams & Co.

D. Pasahow, Edward J., Microcomputer Interfacing, New York, New York, McGraw-Hill Book Co., 1981.

E. Staugaard, Andrew C., Microprocessor Interfacing, Benton Harbor, Michigan, Heath Co., 1982.

F. Hall, Douglas V. and Marybelle B., Experiments in Microprocessors and Digital System, New York, New York, McGraw-Hill Book Co., 1983.

G. Brey, Barry B., Microprocessor Hardware Interfacing And Applications, Columbus, Ohio, Charles E. Merrill Publishing Co., 1984.

TROUBLESHOOTING MICROPROCESSORS

UNIT V

PROCEDURE SHEET

______1. Study Information sheets.

______2. Study Chapter 12, *Microcomputer Interfacing*, Pasahow.

______3. Review Chapter 12 and Information Sheet.

______4. Complete Unit Test - Troubleshooting Microprocessors.

TROUBLESHOOTING MICROPROCESSOR

UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Pulser - a hand held signal generator which has ± polarity and has input for the necessary chip voltage. Pulsers have fan out of about 50 TTL loads and will generate up to 100 Hz pulses.

B. Logic probe - can detect and store pulse from digital circuits. The LED tells whether a signal is changing, detect pulse train, detect if a frequency is less than 100 Hz.

C. Logic analyzers - a recording device that accepts multiple inputs from TTL, ECL and CMOS devices and correctly analyzes the signals. The stored information can be displayed on the built-in CRT.

D. In-circuit emulator - takes the place in-circuit for a processor. This emulator can check out hardware and software. Also RAM and MPU register can be examined and changed.

E. Software diagnostics - a set of computer programs that detect computer problems if the programs will run. These programs can exercise instruction, memory, and check peripheral operation.

II. Ordered steps to troubleshoot a microcomputer.

Troubleshooting Guide

What to look for
Not plugged in
IC in socket backwards
Wrong type of IC in socket
Lead on IC bent underneath or broken off
Solder bridge
Cold solder joint
Broken trace
Power supply voltage out of tolerance
Stuck line (high or low)
Floating line
Noisy switch
Bad connector
Bad socket
Timing glitch
Bus conflict (especially data bus)
Loading
Noise

INFORMATION SHEET

A. First look for problems.

B. Check power and ground connections.

C. Check chip placement and wire continuity.

D. Use logic probes and pulses to check for stuck or floating lines.

E. Use an oscilloscope to look for noise on a line, incorrect clock period or glitches.

F. Use software to exercise components.

TROUBLESHOOTING MICROPROCESSORS

UNIT V

TEST

NAME____ SCORE__________

1. Match terms associated with troubleshooting microcomputers to their correct definitions. Place the correct number in the blank.

_____a. A set of computer programs that detect computer problems if the programs will run.

_____b. Can detect and store pulse from digital circuits.

_____c. A hand-held signal generator which has ± polarity and has input for the necessary clip voltage.

_____d. Takes the place in-circuit for a processor.

_____e. A recording device that accepts multiple inputs from TTL, ECL and CMOS devices and correctly analyzes the signals.

1. Software diagnostics
2. Logic analyzers
3. In-circuit emulator
4. Pulser
5. Logic probe

2. List the ordered steps to properly troubleshoot a microcomputer.

a.

b.

c.

d.

e.

f.

3. End of test. STOP. Have your instructor evaluate your test. If you receive a score of 80 percent or more, CONGRATULATIONS! You have finished this Section. Continue on to the next Section. If additional study is necessary, ask your instructor about study requirements and possible retesting.

TROUBLESHOOTING MICROPROCESSOR

UNIT V

TEST ANSWERS

1. a. 1
   b. 5
   c. 4
   d. 3
   e. 2

2. a. Look for problems.
   b. Check power and ground connections.
   c. Check clip placement and wire continuity.
   d. Use logic probes and pulses to check for stuck or floating lines.
   e. Use an oscilloscope to look for noise on a line, incorrect clock period or glitches.
   f. Use software to exercise components.

AUTOMATED SYSTEMS

AUTOMATED SYSTEMS

Objective

After completing this unit, the student should be able to install, calibrate, inspect, modify, and troubleshoot an automated system comprised of electrical, hydraulic, pneurmatic and electronic subsystems controlled by an interfaced microcomputer. This knowledge will be shown by the student demonstrating the ability to design, assemble, and troubleshoot a complete automated system utilizing equipment from each course.

Specific Objective

After completing this unit, the student should be able to:

1. Troubleshoot and repair as electrical systems.
2. Troubleshoot and repair a mechanical system.
3. Troubleshoot and repair an electronic systems.
4. Troubleshoot and repair a hydraulic systems.
5. Troubleshoot and repair a pneumatic system.
6. Troubleshoot and repair a microcomputer system and interface.
7. Operate automated equipment to calibrate and align integrated system.
8. Evaluate automated system performance using on line programs.
9. Write and modify programs using an industrial language to check and diagnose system performance.
10. Maintain electrical, hydraulic, pneumatic, and electronic circuits to improve system performance.

Specific Objective

11. Suspect production system for conformance to prescribed specifications.
12. Predict preventive maintenance.
13. Recommend changes to simplify assembly or maintenance.

AUTOMATED SYSTEMS

SUGGESTED ACTIVITIES

I. Instructor

   A. Provide students with objective sheet.

   B. Discuss unit and specific objective.

   C. Demonstrate a complete "automated system" utilizing equipment from each course.

   D. Discuss the original system project that the students (in groups of two) will be required to design, assemble, and operate using equipment from each course.

   E. Discuss that each student will be required to troubleshoot and repair the "bags" that will be put into their project.

   F. Assert students in selecting an original project.

   G. Assert students in designing and assembling their project.

   H. Put "bags" in each students project.

II. Student

   A. Read the objective sheet.

   B. Select a project partner.

   C. Select an original project.

   D. Design, assemble, and operate project.

   E. Individually troubleshoot and repair their project.